Time Stamping

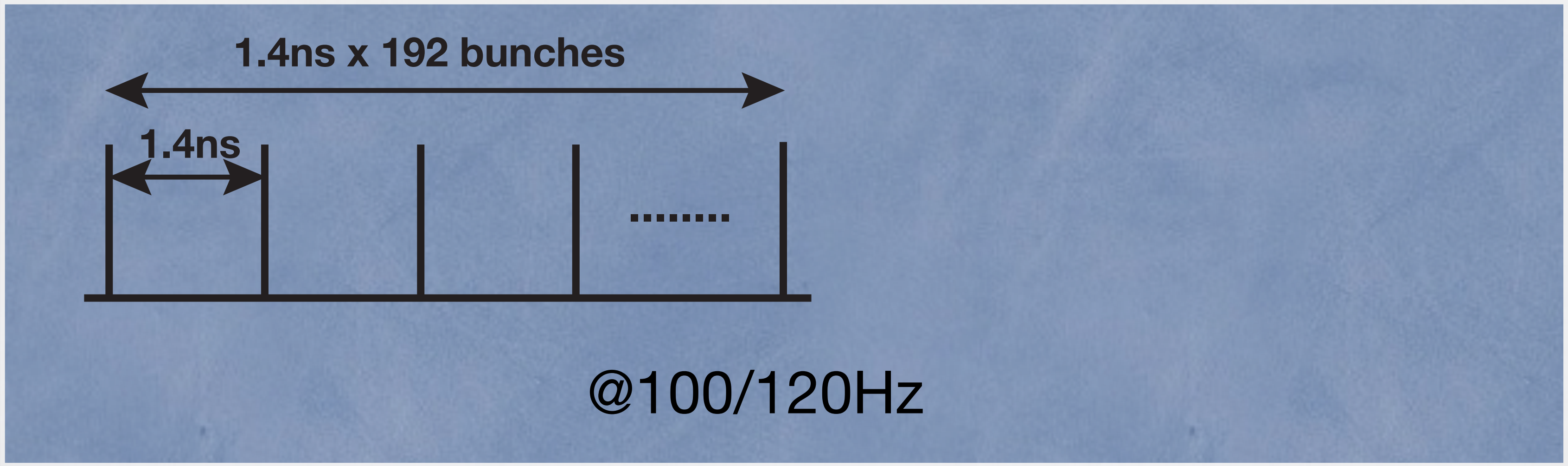
CDC/TPC Comparison Studies

Keisuke Fujii, KEK

Why Time Stamping?

- JLC/NLC Bunch Structure and Min-Jet BG

JLC/NLC Bunch Structure and Min-Jet BG



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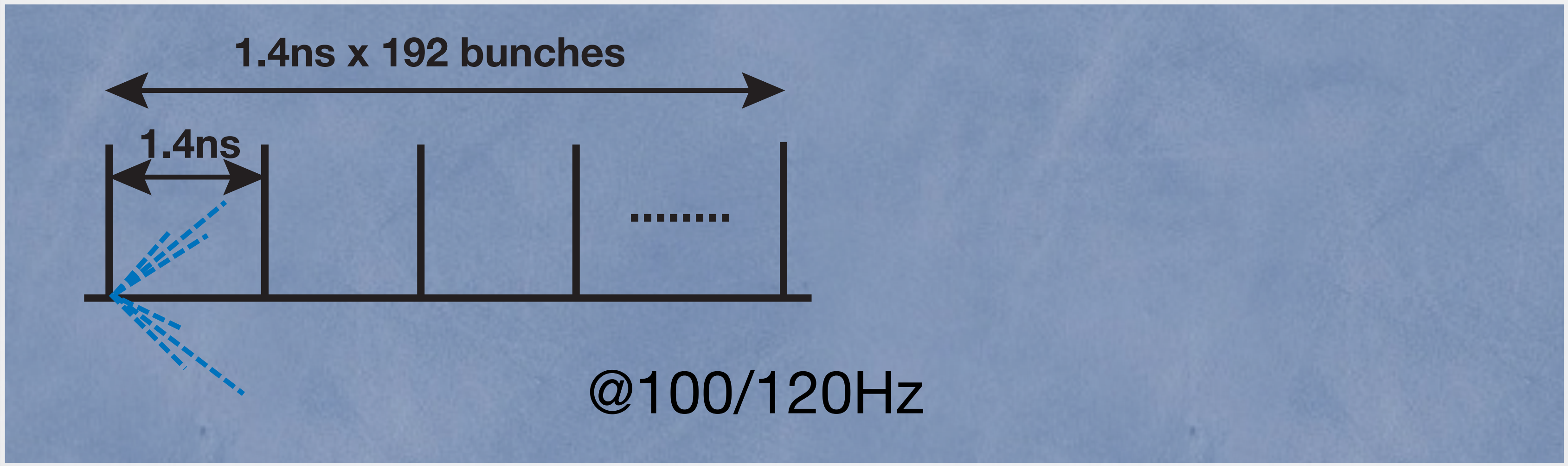

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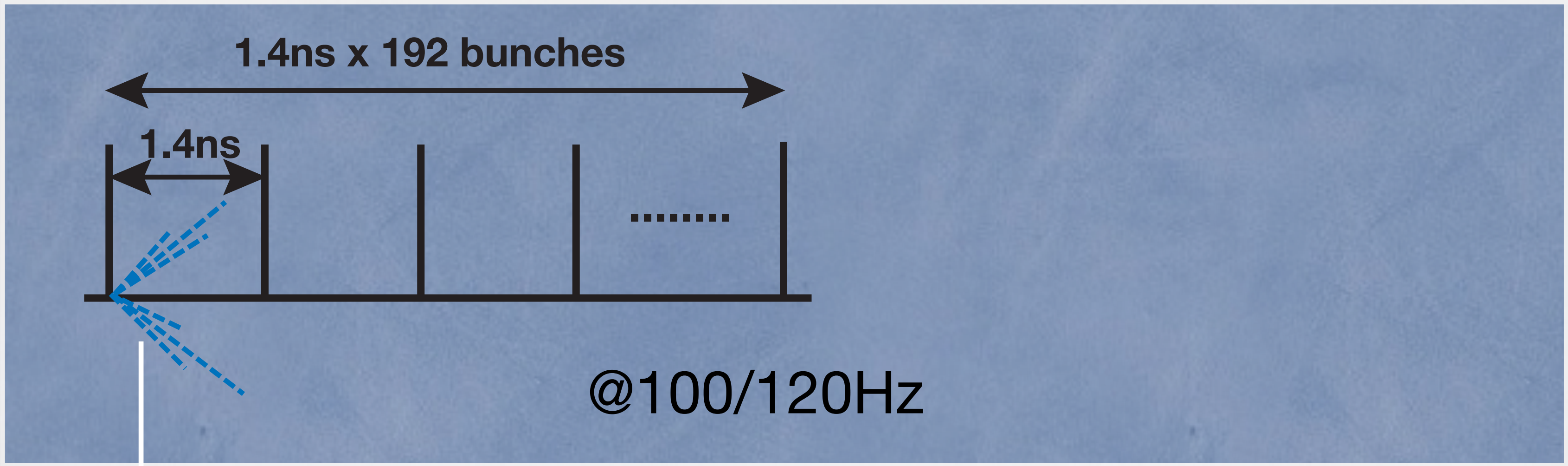

2-Photon Mini-Jet Production

$$\langle E \rangle \simeq 2.5 \text{ GeV}$$
$$\langle n_{\rm ch} \rangle \simeq 5$$

in chamber acceptance

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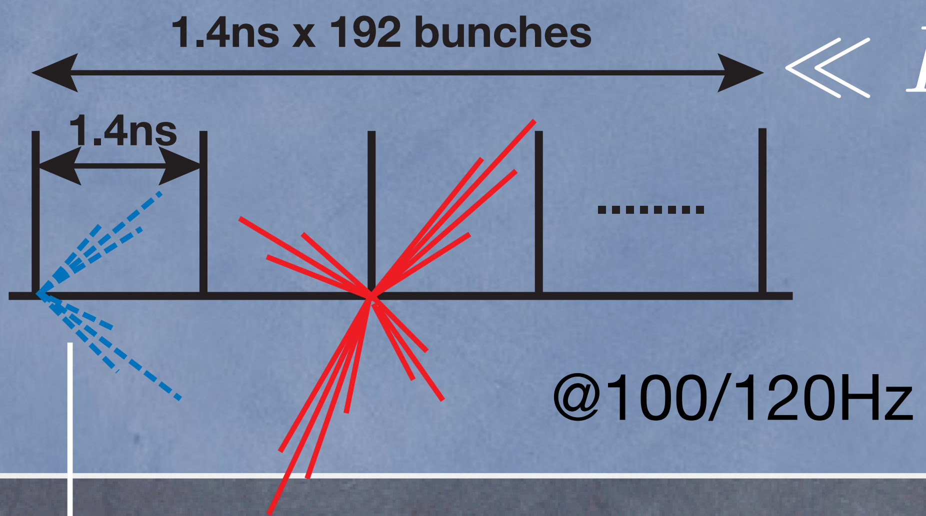

$$\ll L_{\mathrm{drift}}^{\mathrm{max}} / v_{\mathrm{drift}}$$

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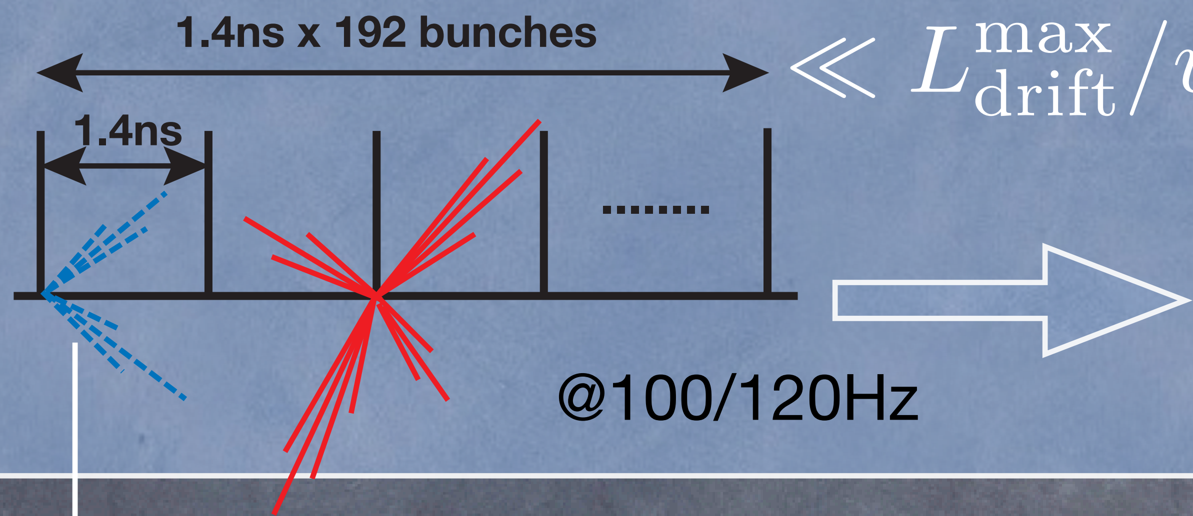

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All the tracks will be recorded
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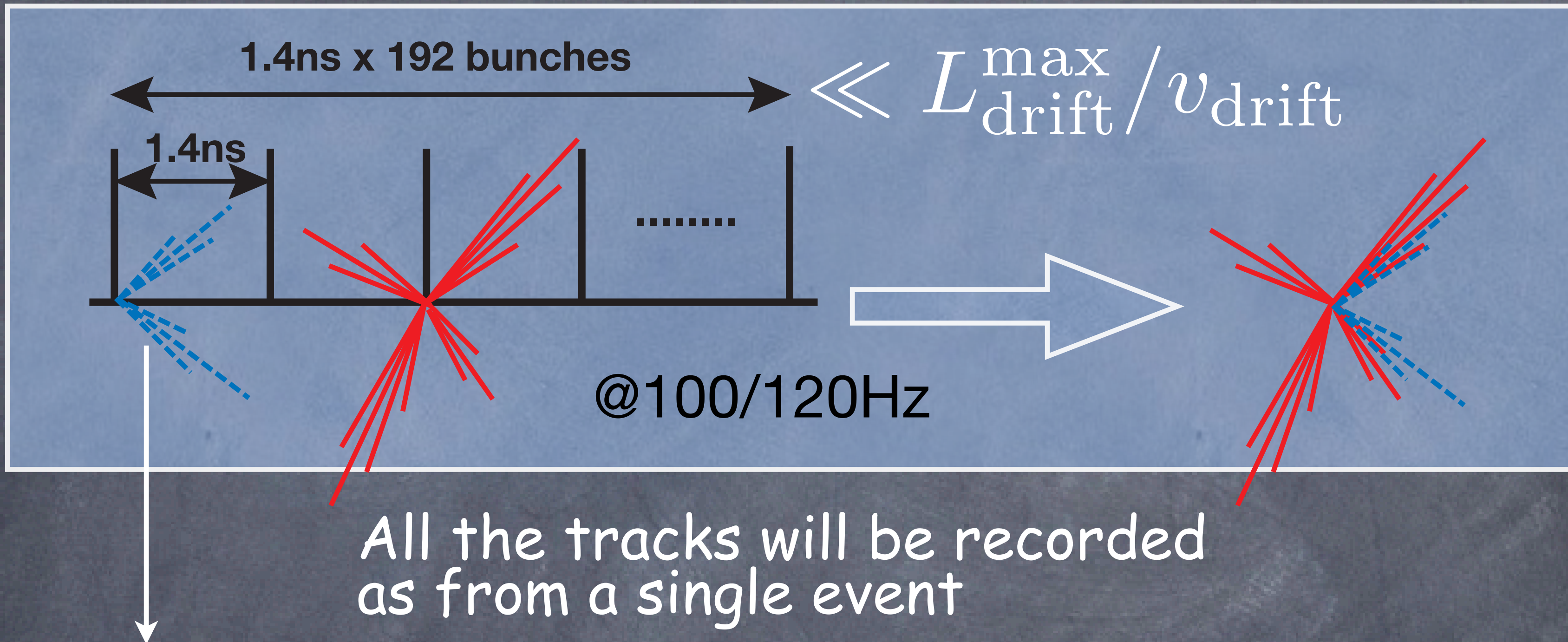

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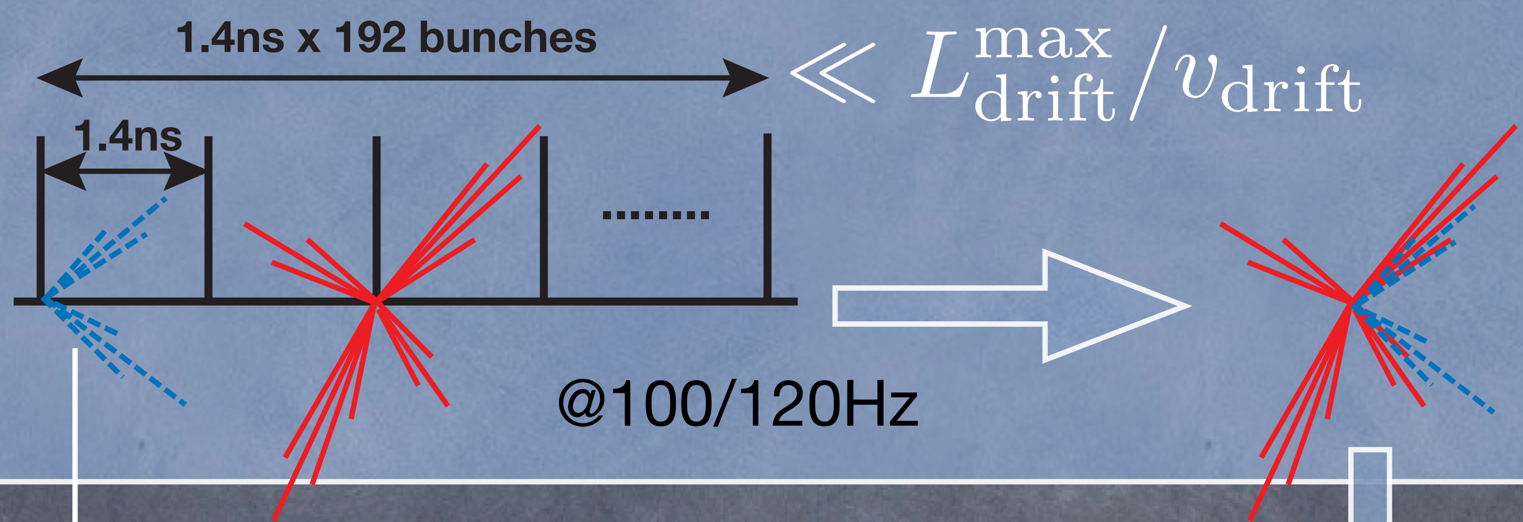

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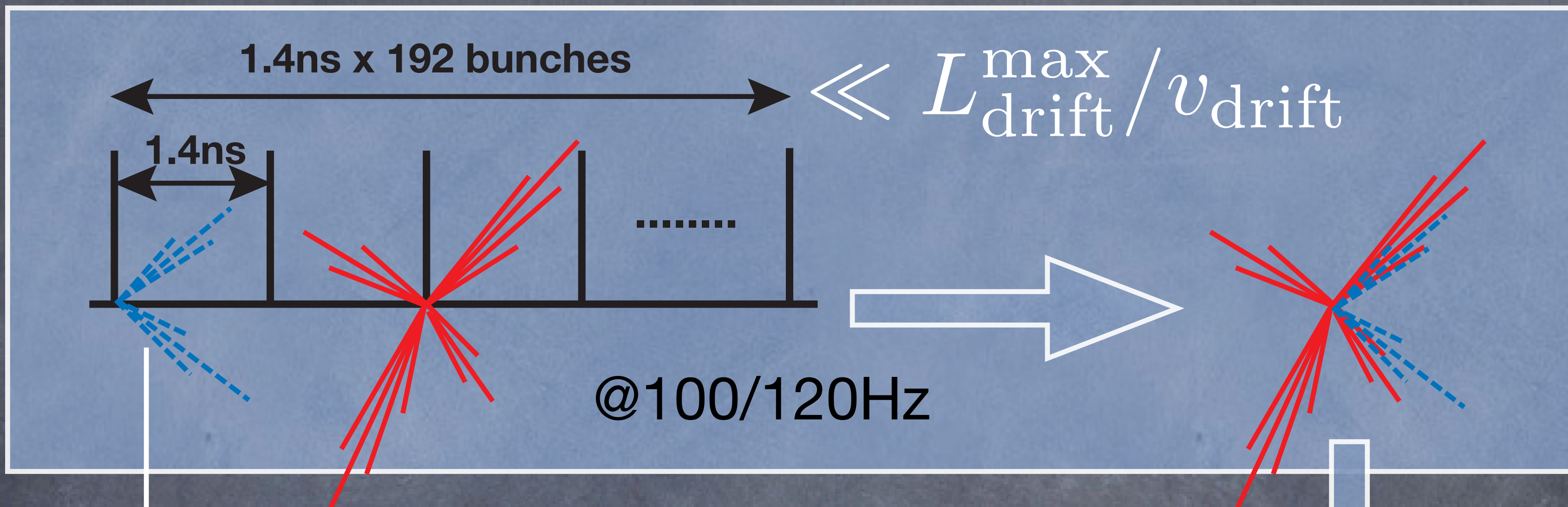

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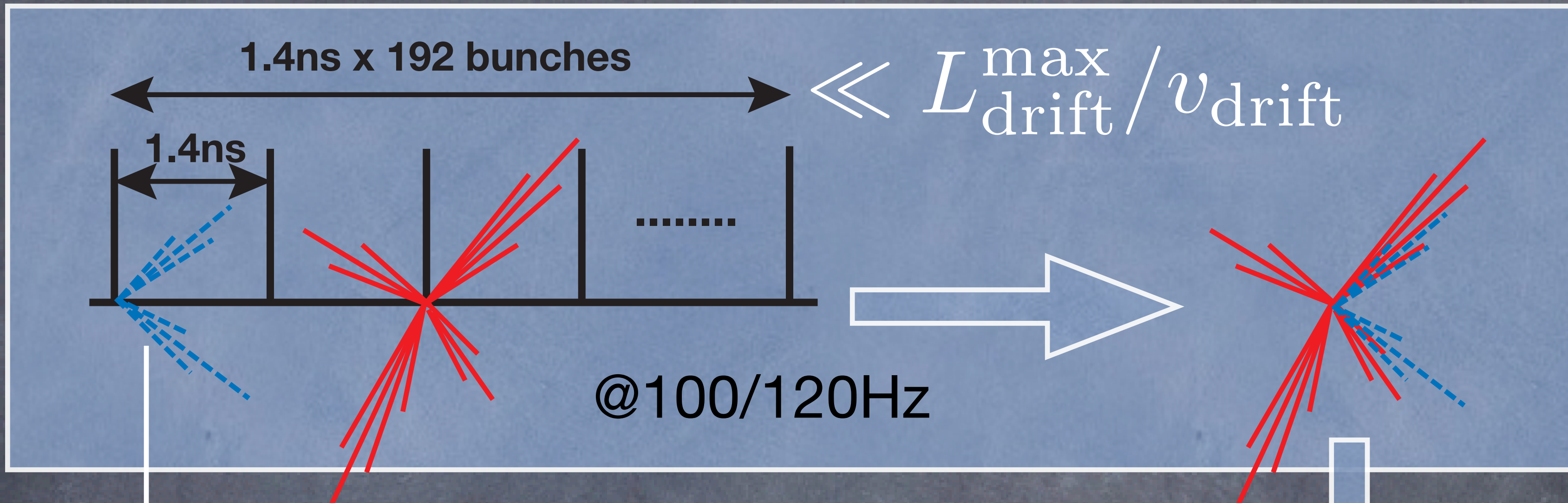

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Degradation of M-jet resolution

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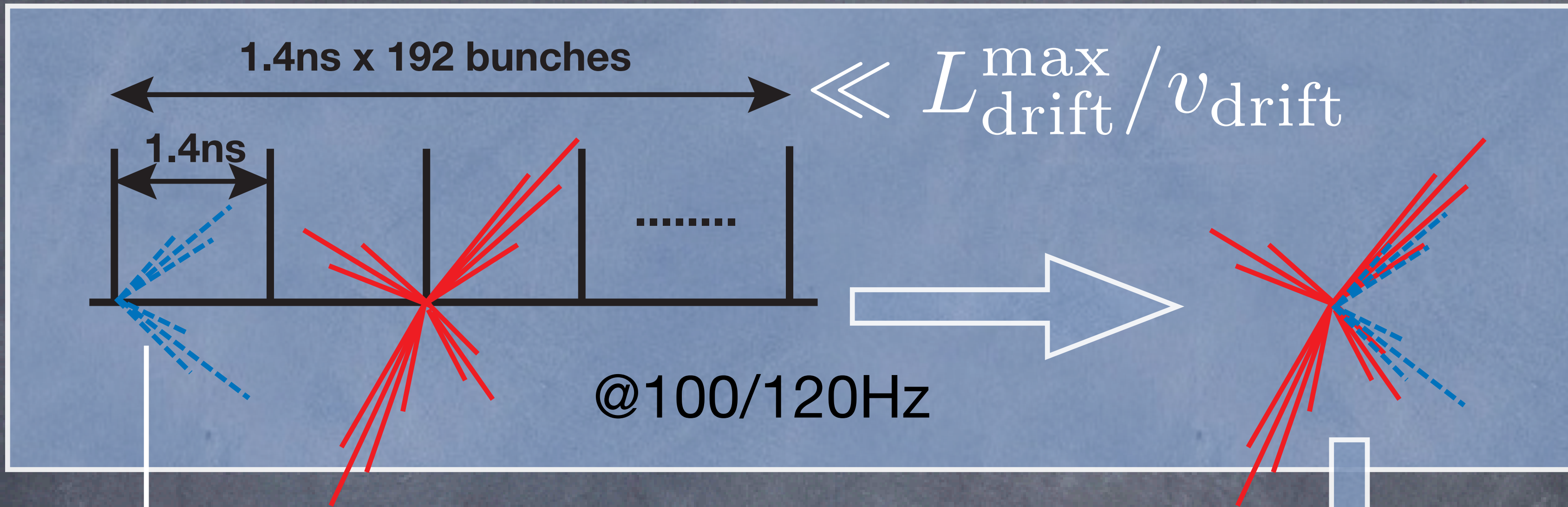

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....

How to Time-Stamp a Track?

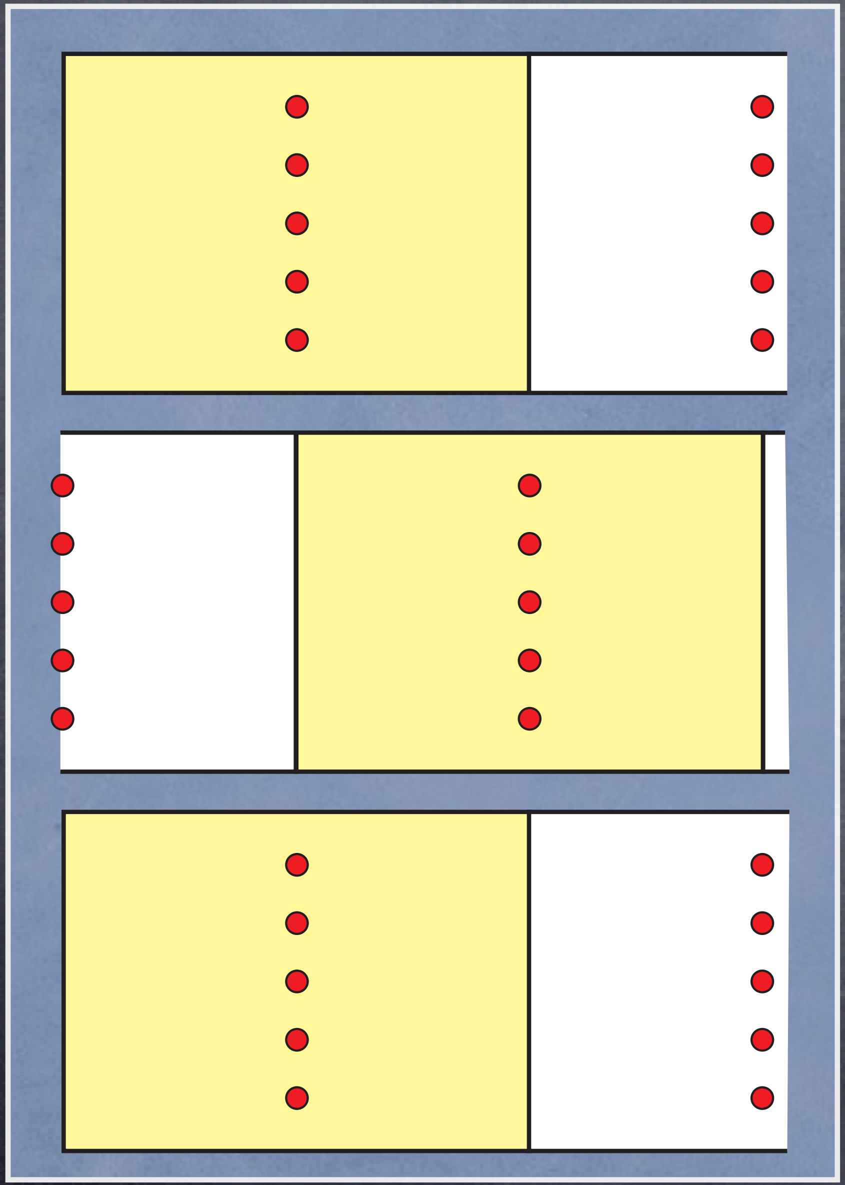
- In the Case of JLC-CDC

- In the Case of JLC-CDC

Staggered Cells

In the Case of JLC-CDC

Staggered Cells



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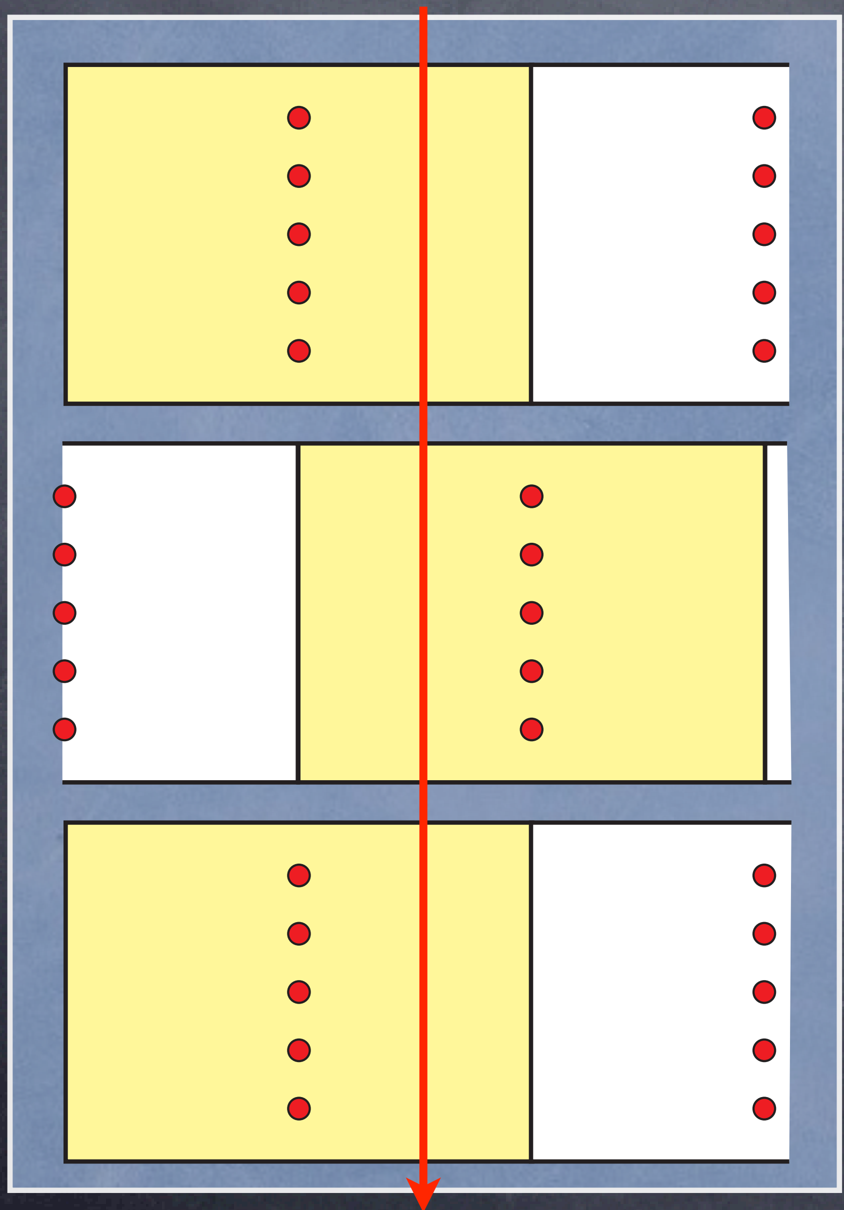

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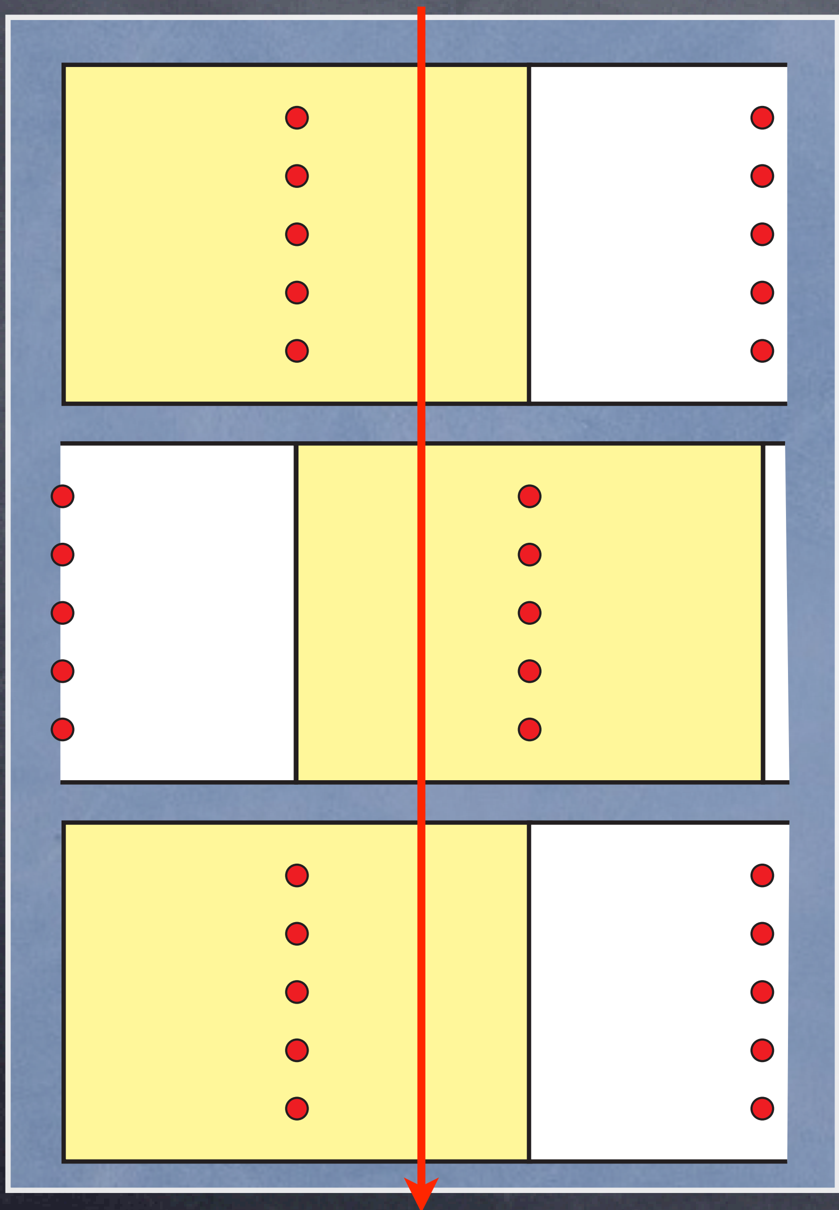

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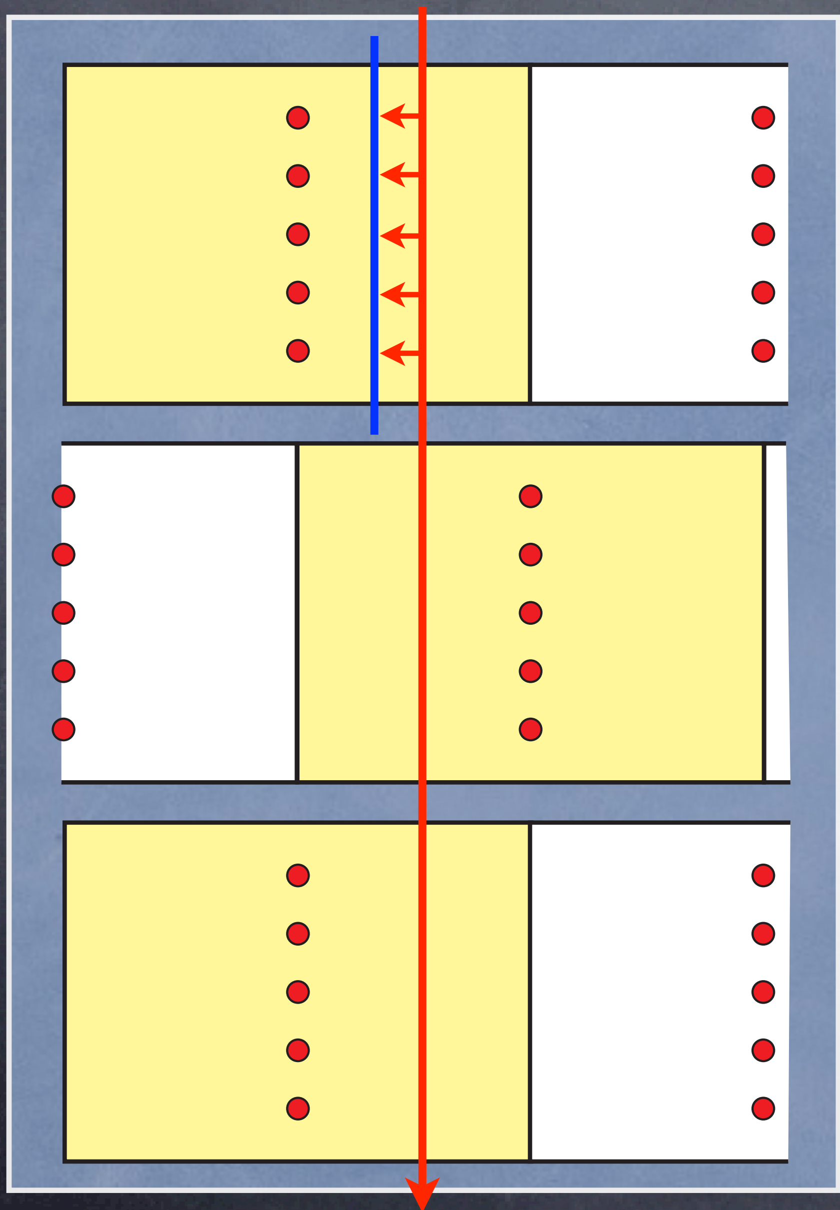

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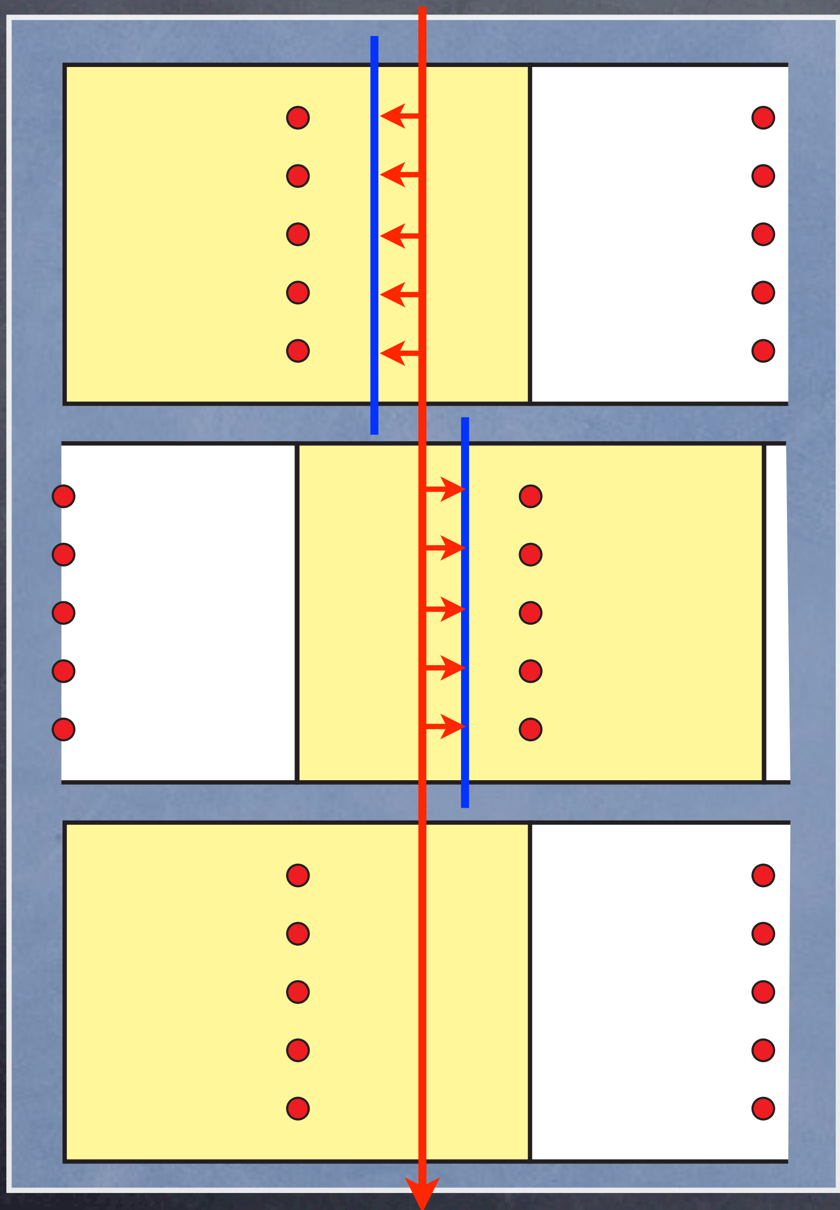

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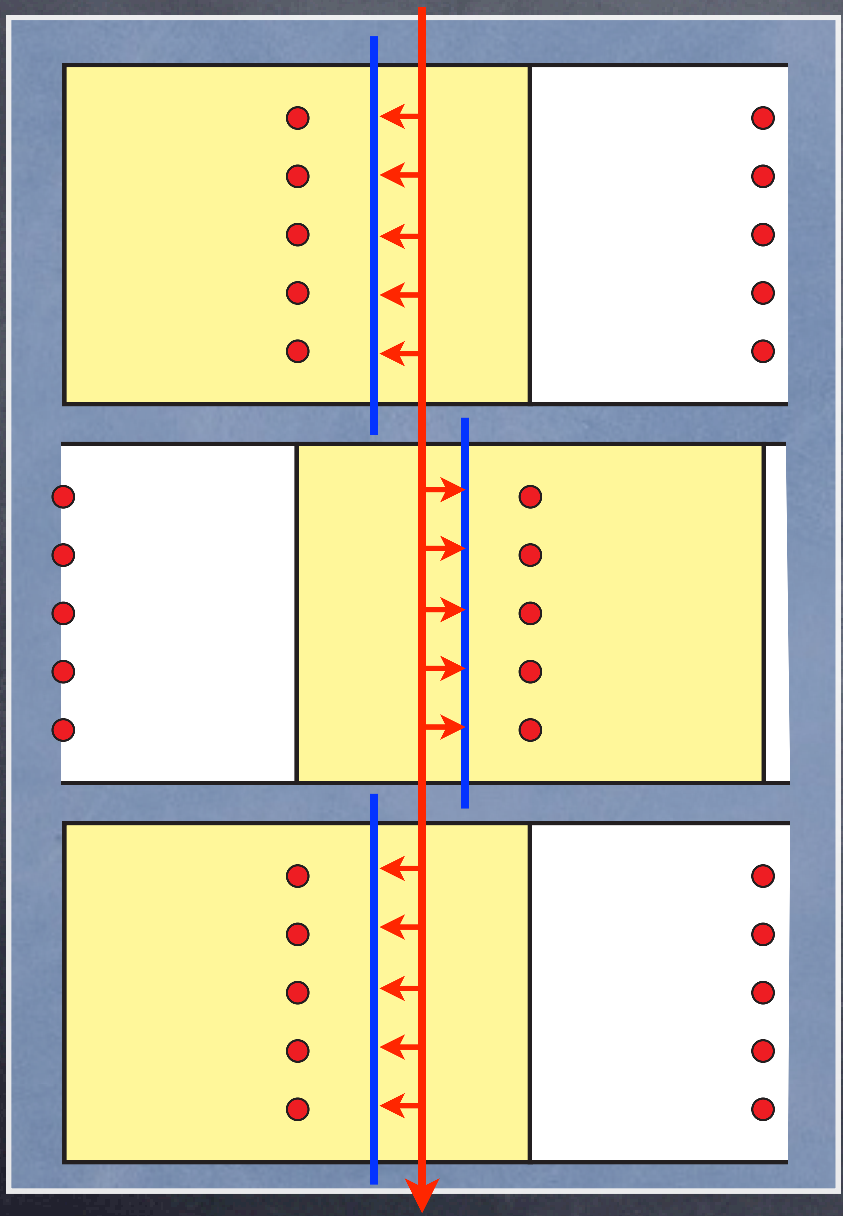

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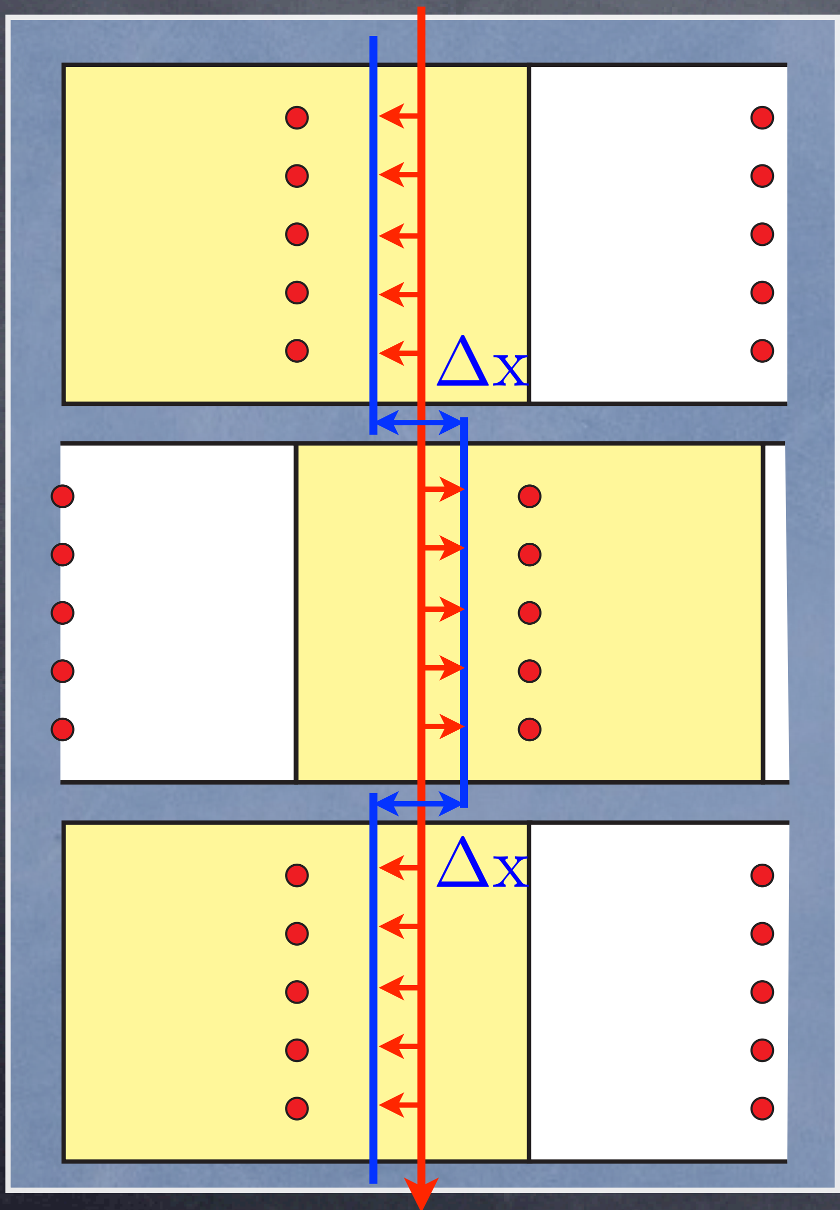

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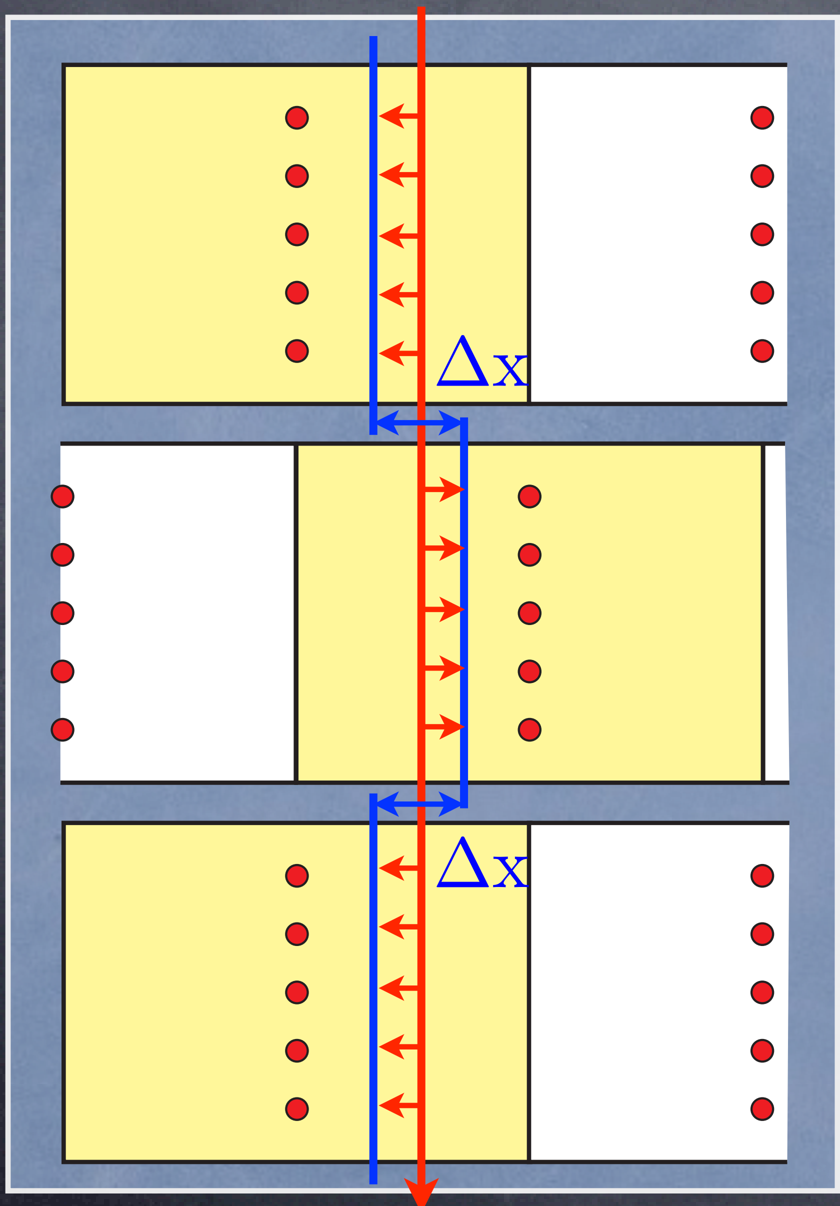

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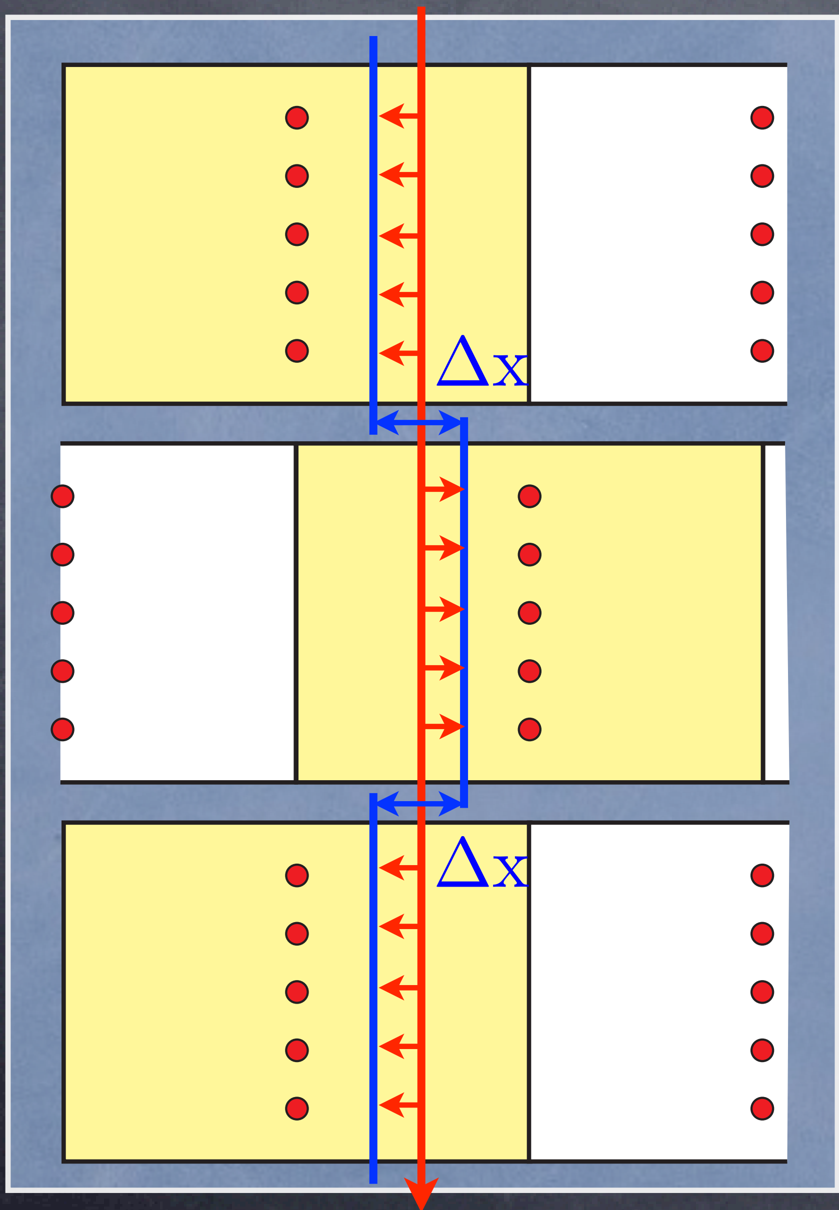

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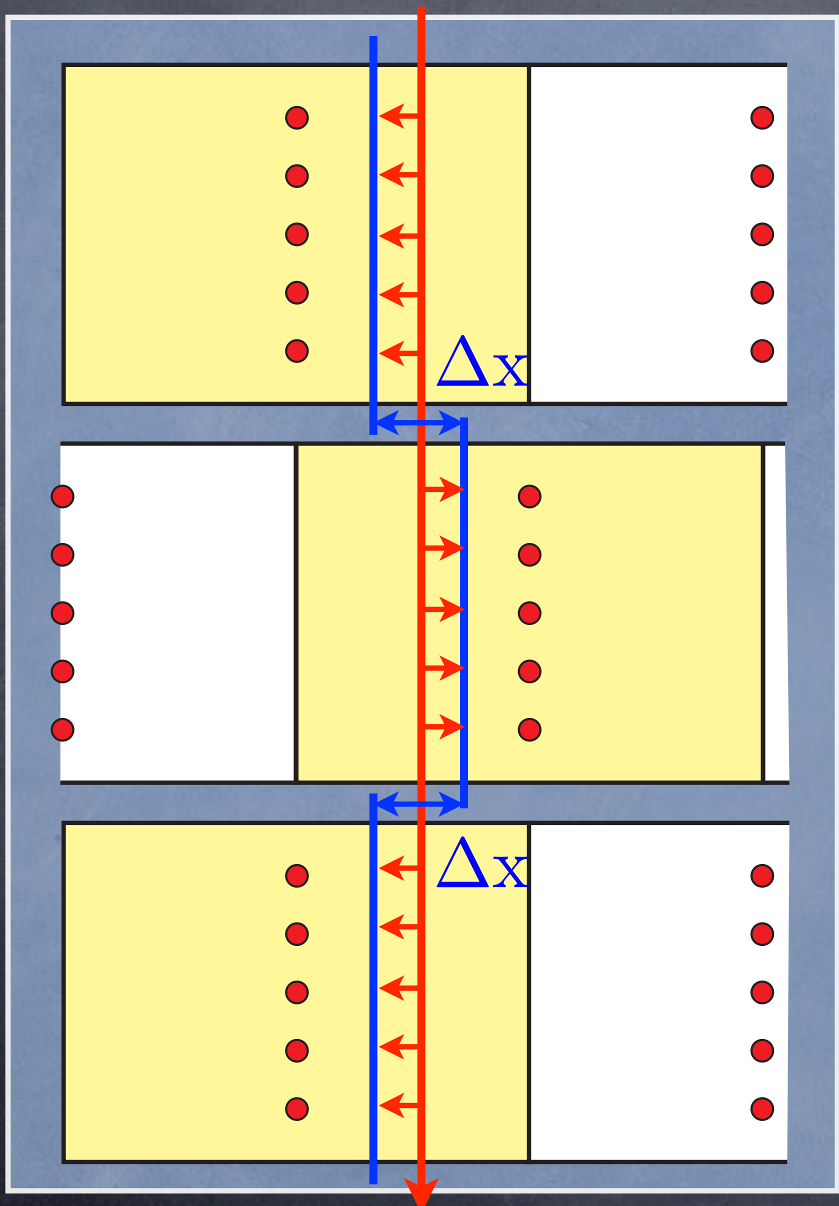

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$$\sigma_{\Delta T_0} \simeq \frac{\sigma_{\mathrm{xy}}}{v_{\mathrm{drift}}\sqrt{n}}$$

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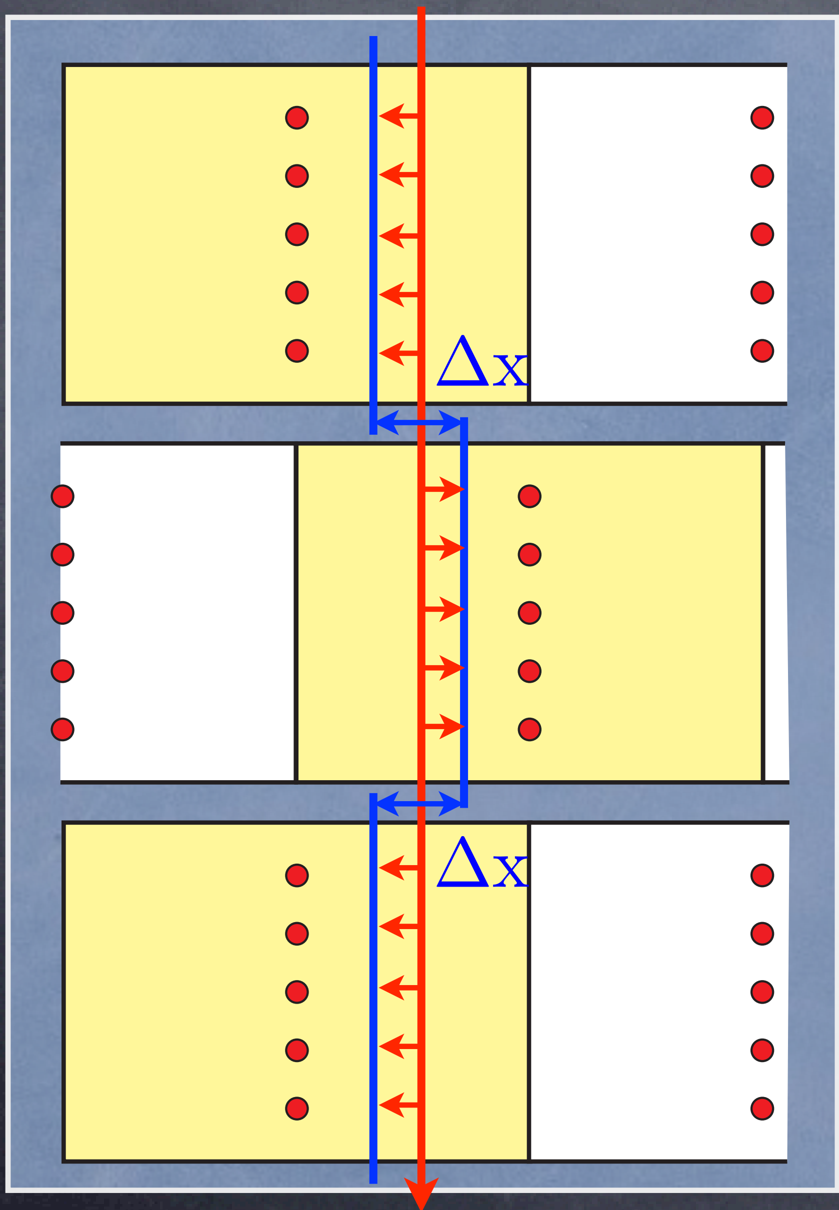

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$$\sigma_{\mathrm{xy}} = 85\ \mu\mathrm{m}$$
$$v_{\mathrm{drift}} = 0.7\ \mathrm{cm}/\mu\mathrm{s}$$
$$n = 50$$

$$\boxed{\sigma_{\Delta T_0} \simeq 1.7\ \mathrm{ns}}$$

- In the Case of TPC

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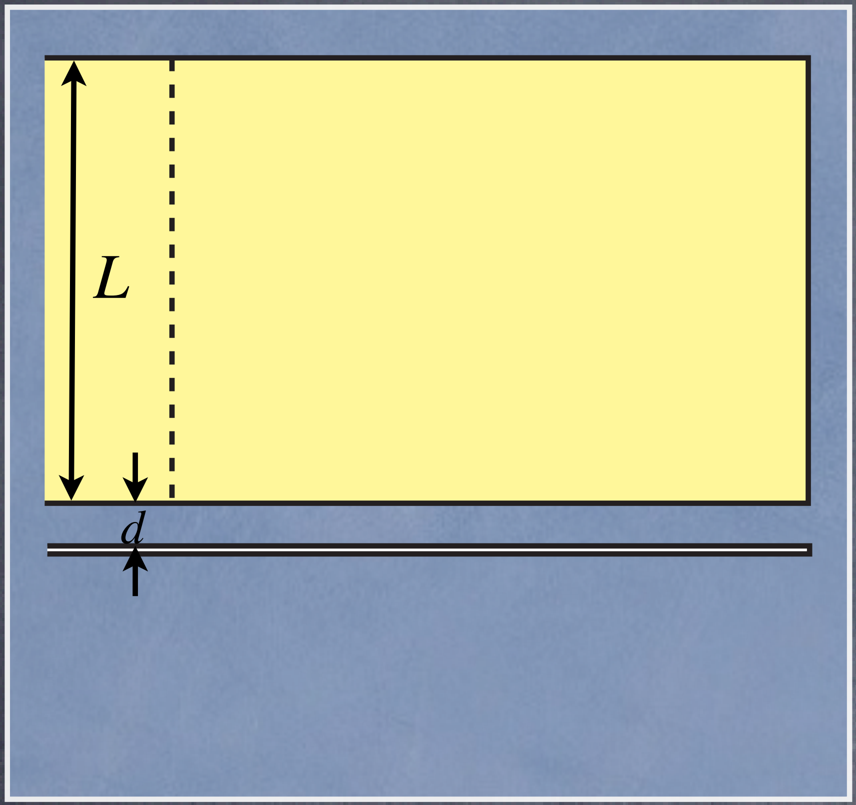

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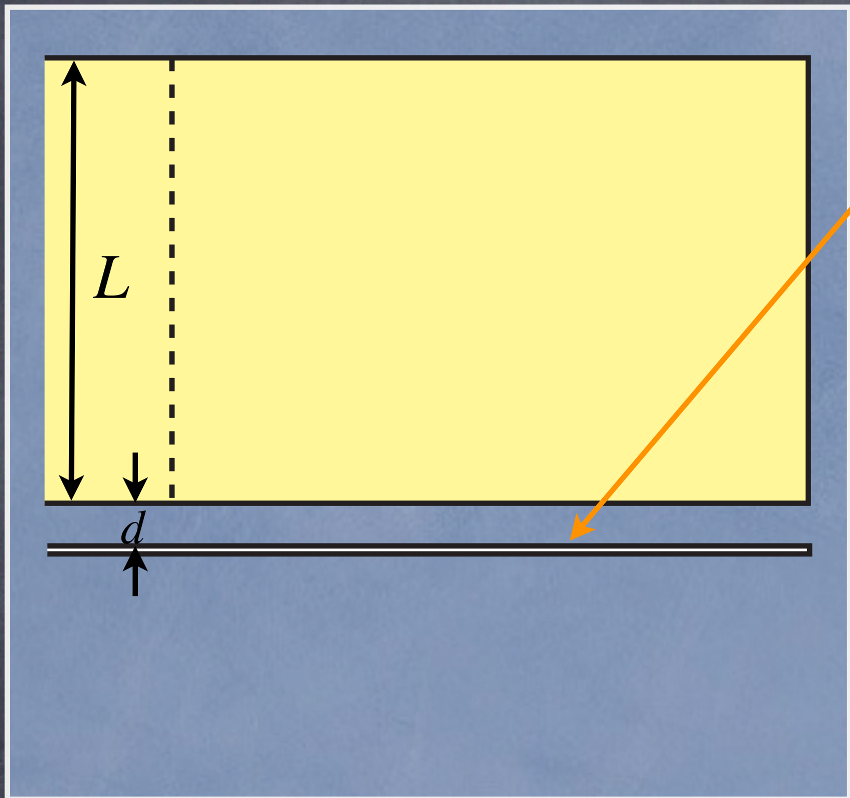

External Z Detector (T0 Device)

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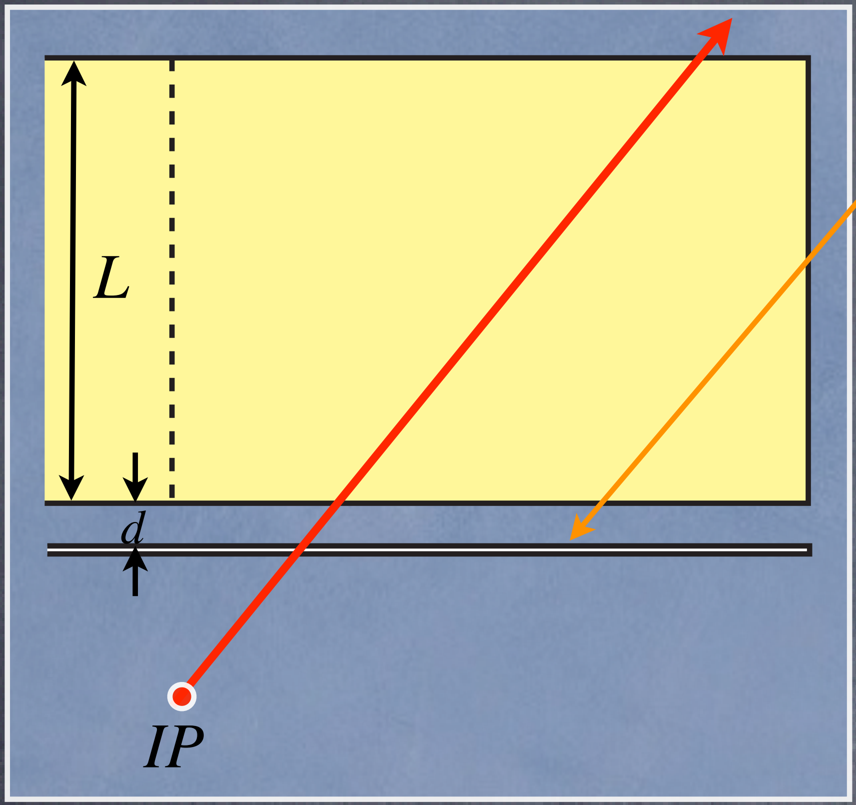

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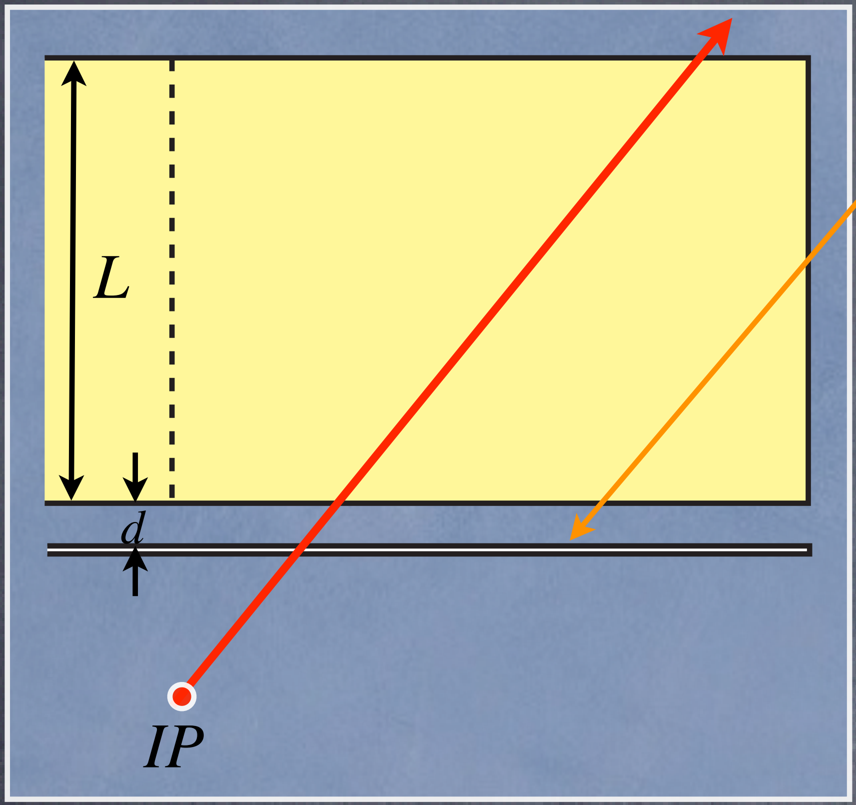

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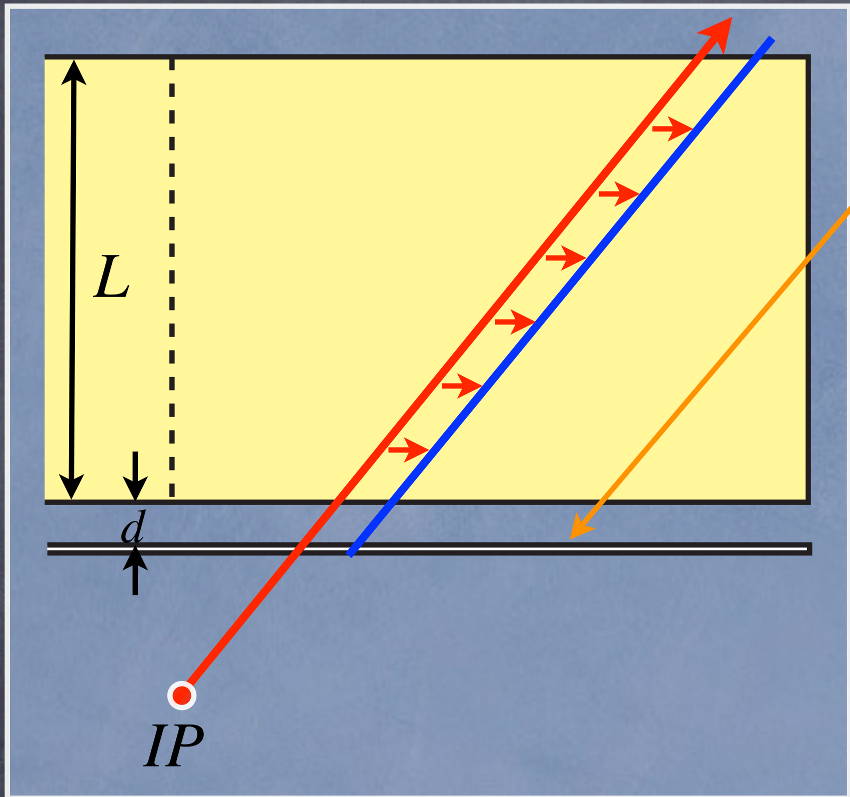

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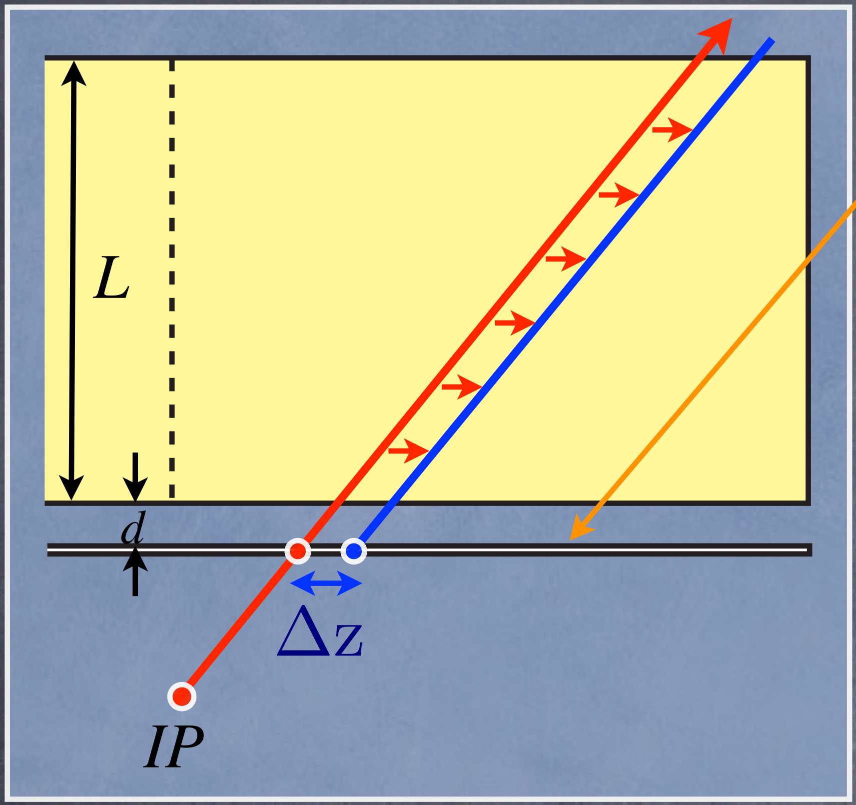

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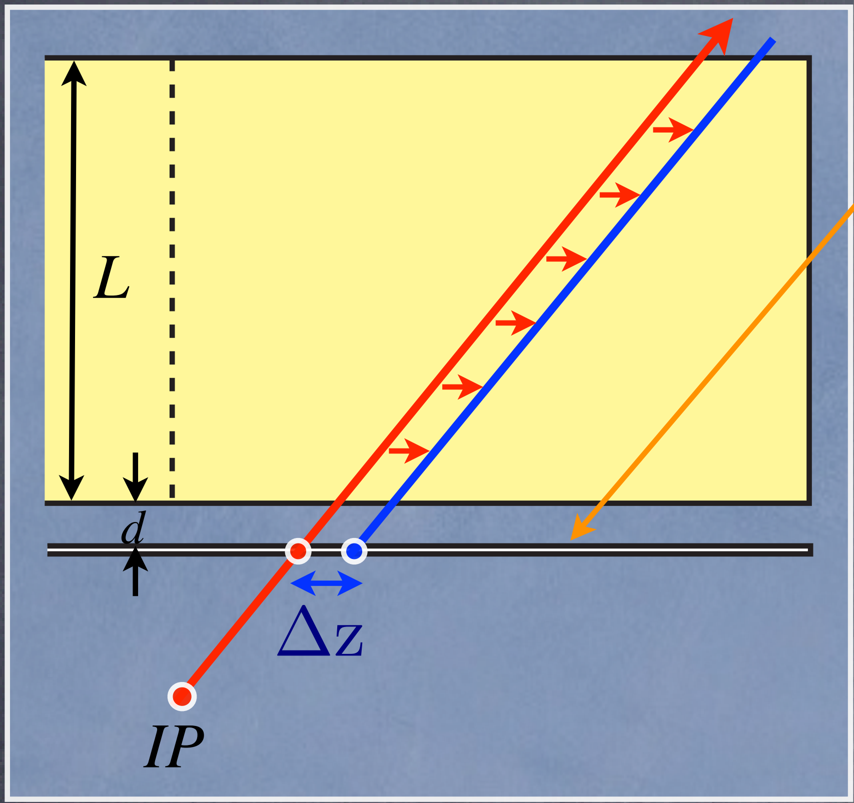

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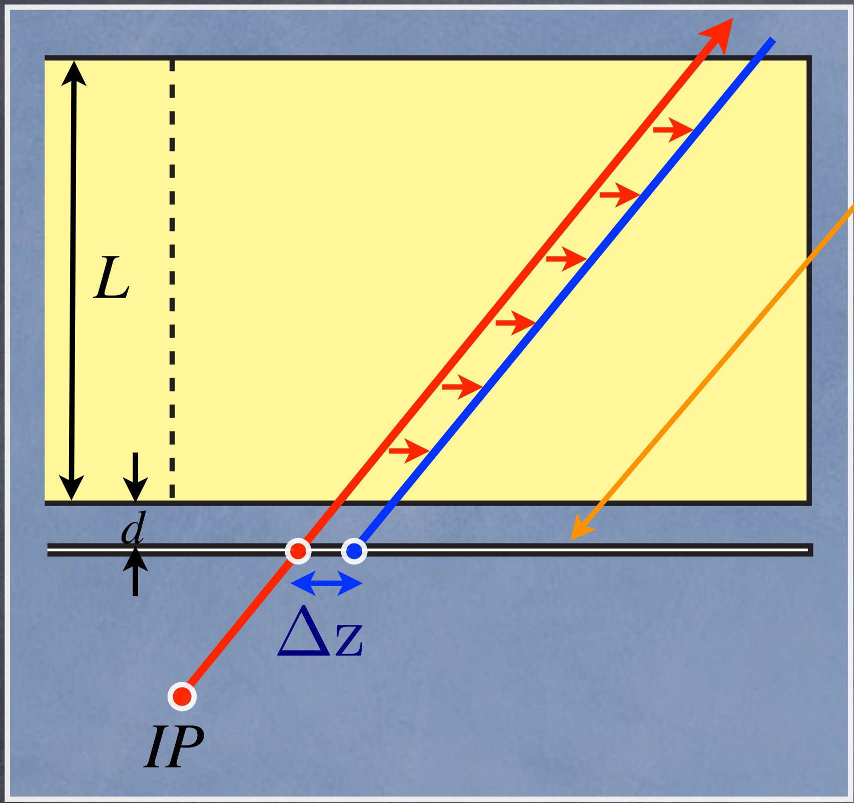

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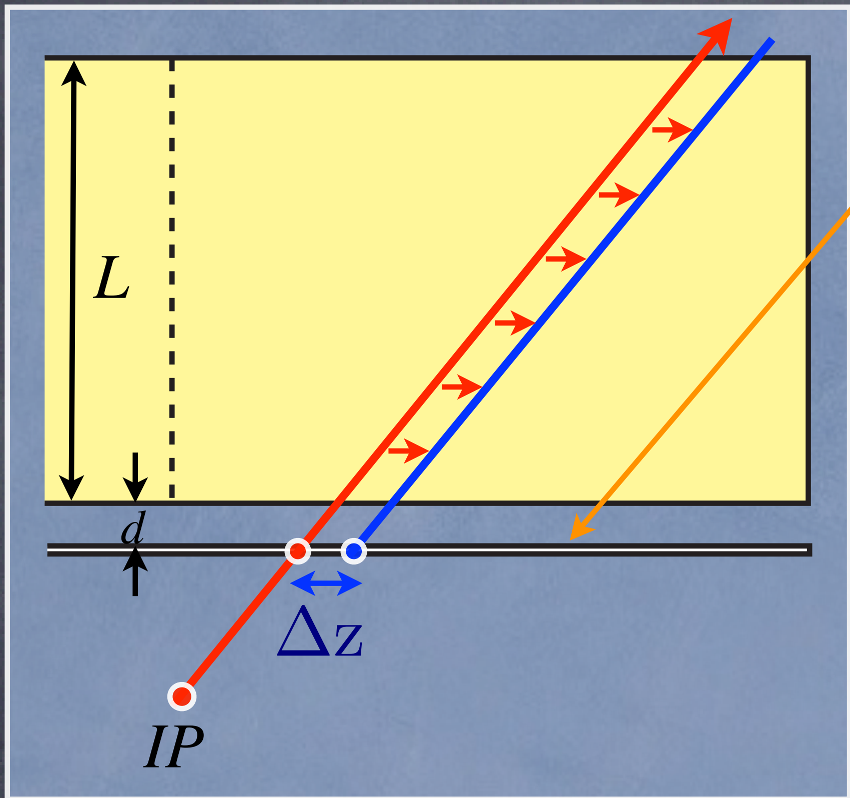

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$$\Delta z = v_{\mathrm{drift}} \times \Delta T_0$$

Naively we expect

$$\sigma_{\Delta T_0} \simeq \frac{2\sigma_z}{v_{\mathrm{drift}}\sqrt{n}} \left[1 + 3\left(\frac{d}{L}\right) + 3\left(\frac{d}{L}\right)^2 \right]^{-\frac{1}{2}}$$

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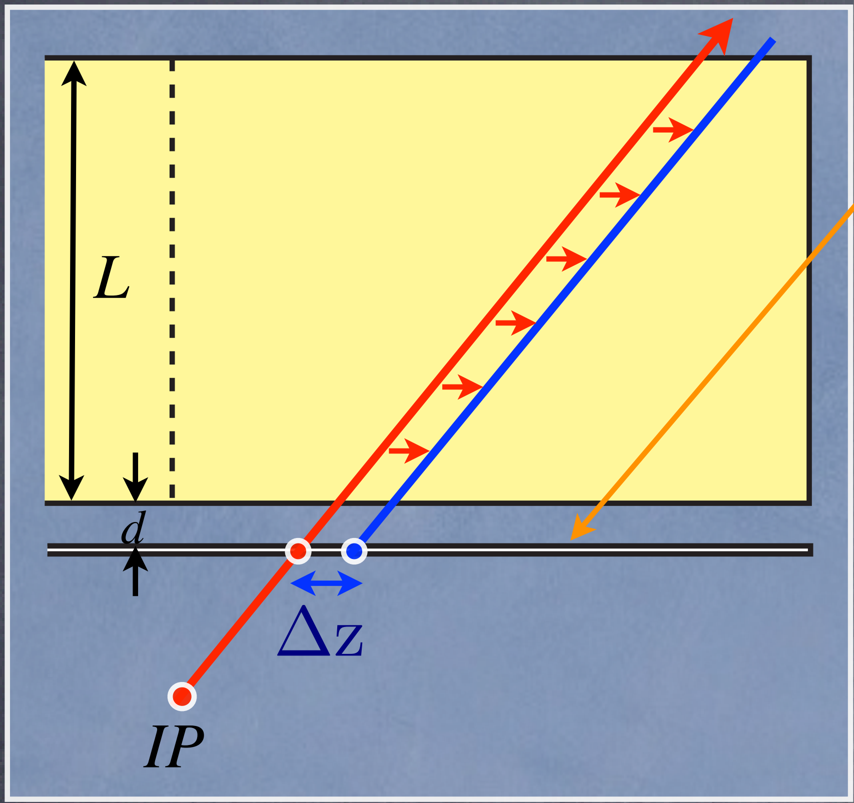

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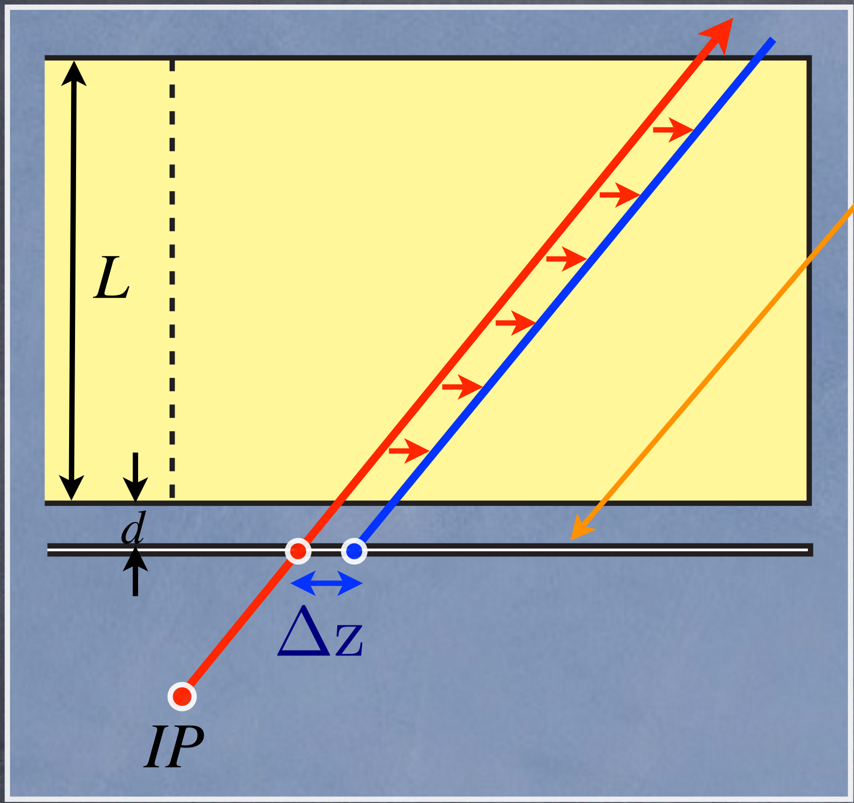

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Assuming that Z resolution of the external detector is negligible

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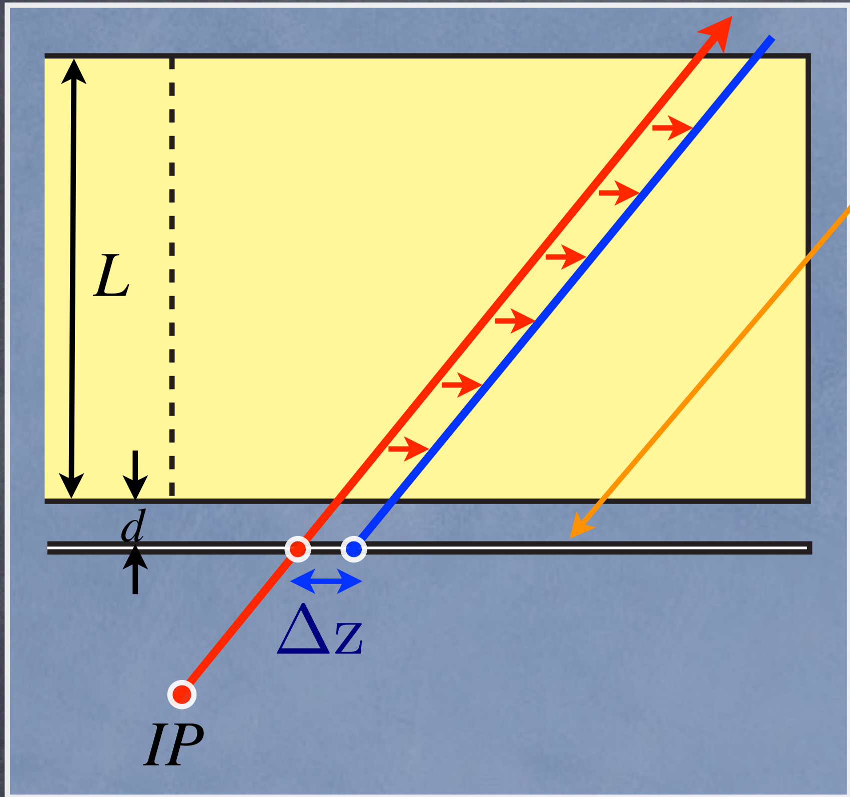

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$$\sigma_{\mathrm{z}} = 500\ \mu\mathrm{m}$$
$$v_{\mathrm{drift}} = 5\ \mathrm{cm}/\mu\mathrm{s}$$
$$n = 120$$

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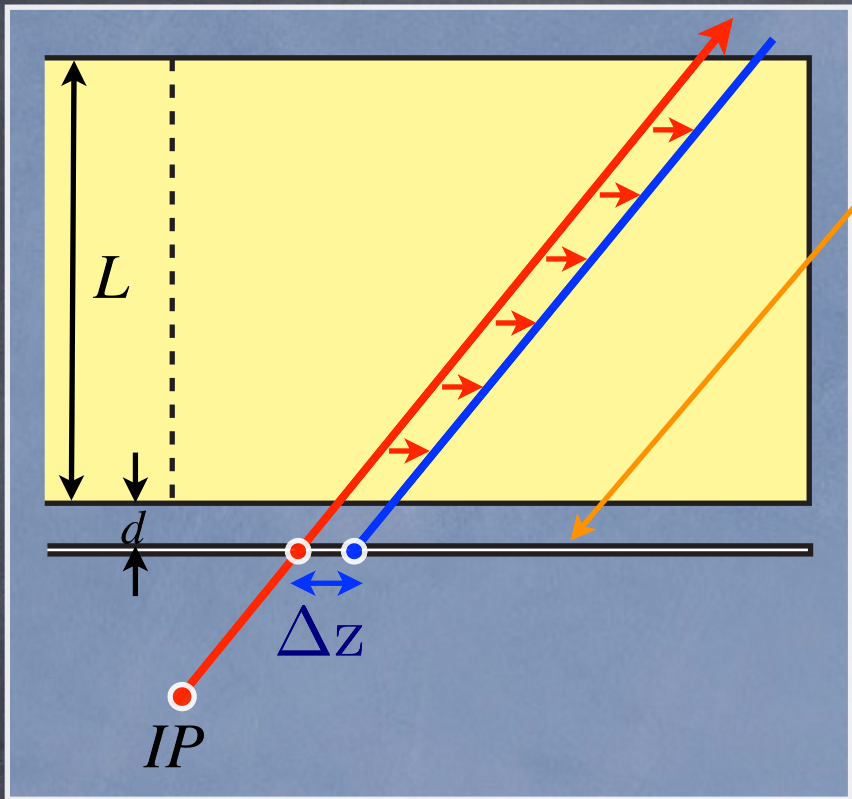

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$$\sigma_{\mathrm{z}} = 500\ \mu\mathrm{m}$$
$$v_{\mathrm{drift}} = 5\ \mathrm{cm}/\mu\mathrm{s}$$
$$n = 120$$

$$\sigma_{\Delta T_0} \simeq 2.0\ \mathrm{ns}$$

More Realistic Estimation

Helix Fit CDC Hits with T0
as an Additional Fit Parameter

CDC Case

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- Chi2 Distribution (axial only)

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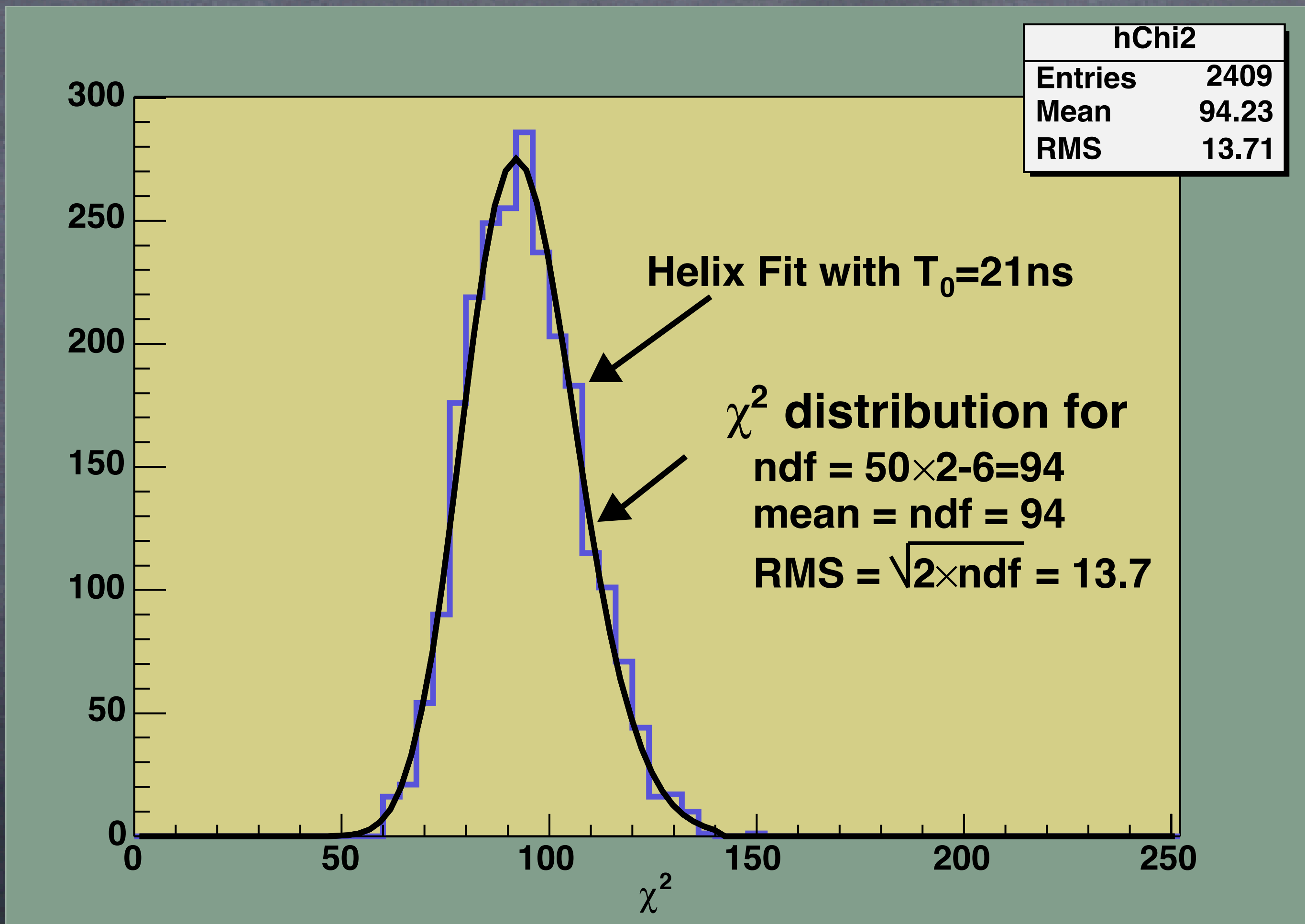

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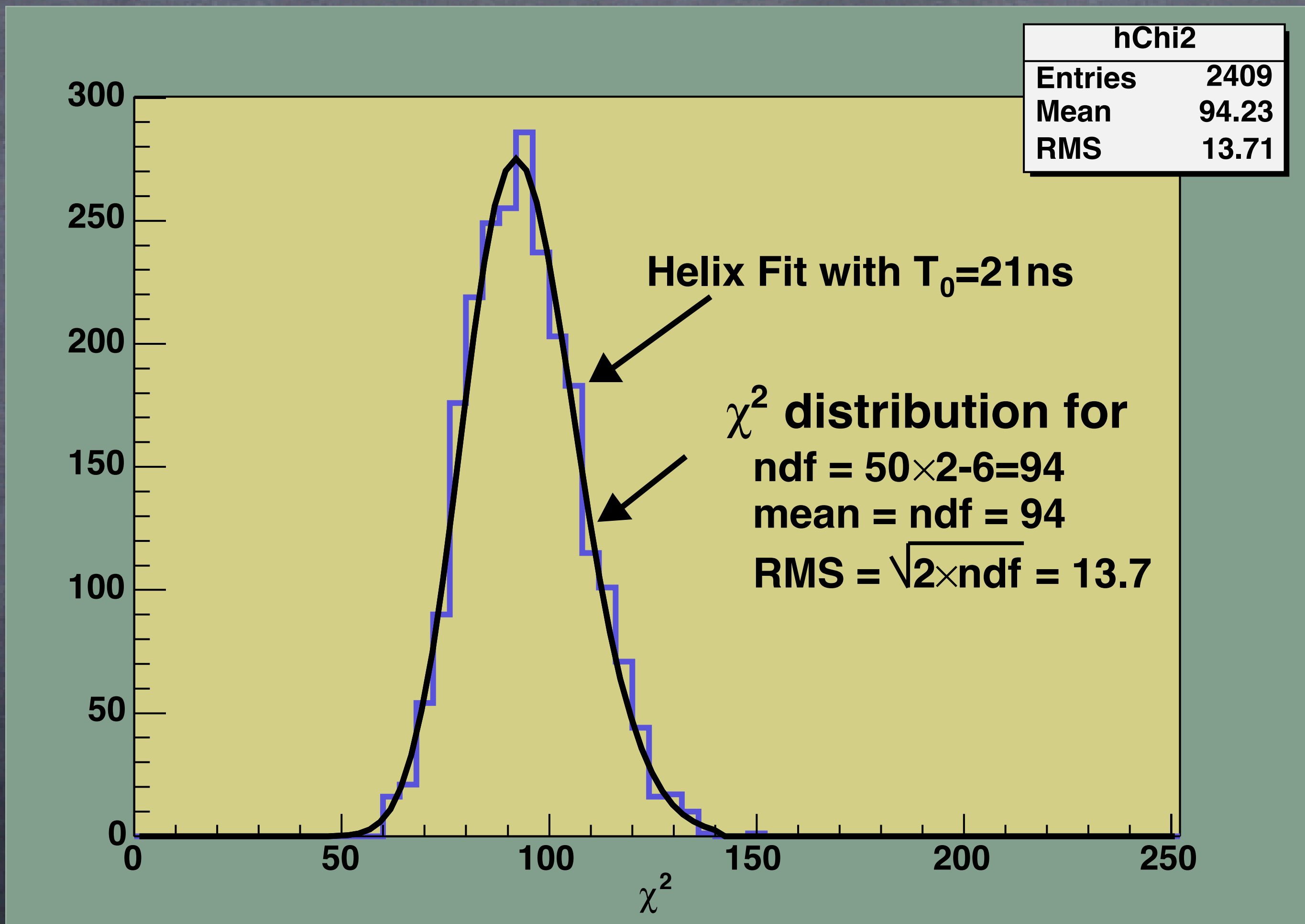

→ Fit seems OK!

- T0 from Helix Fit (axial only, 100GeV)

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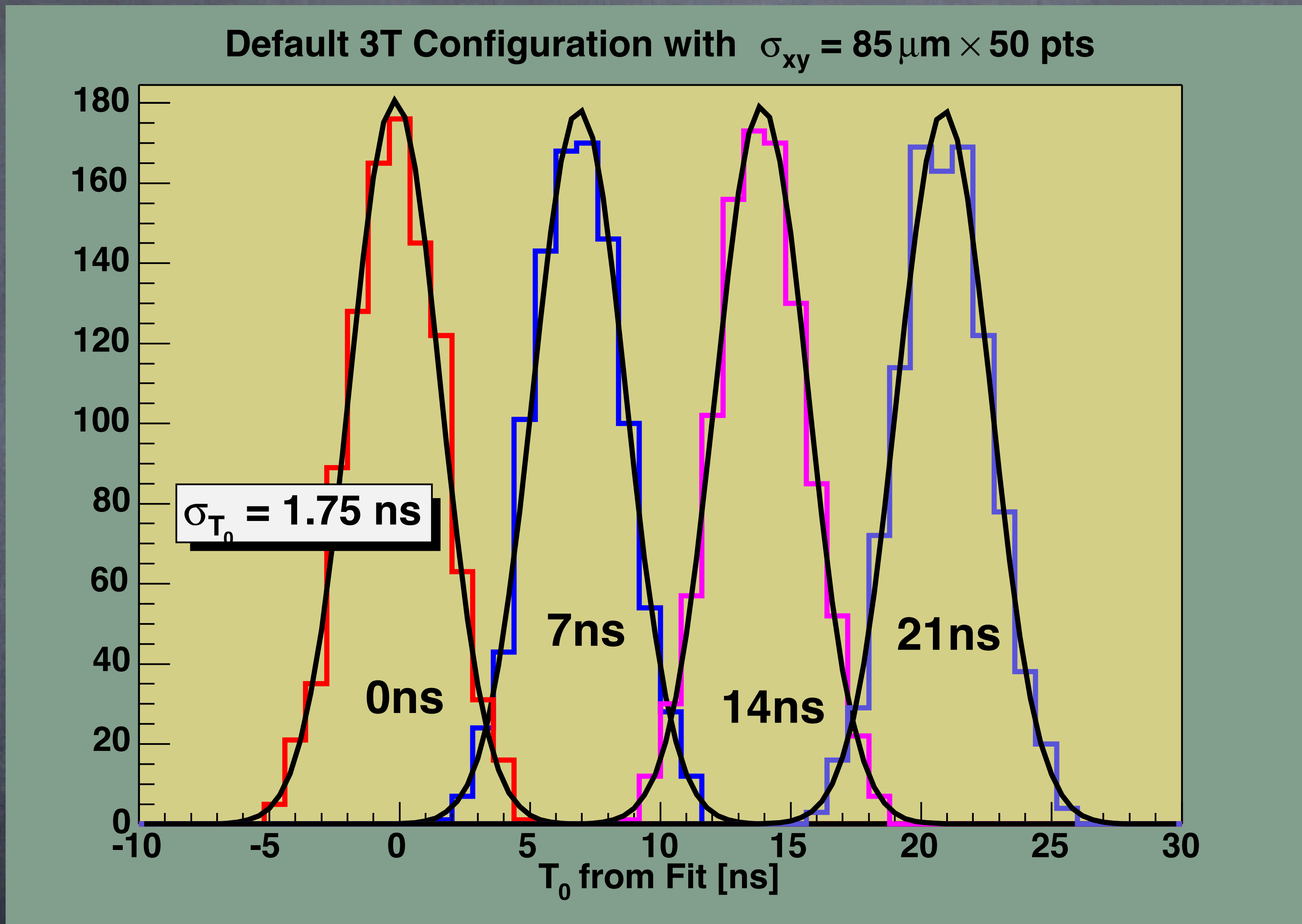

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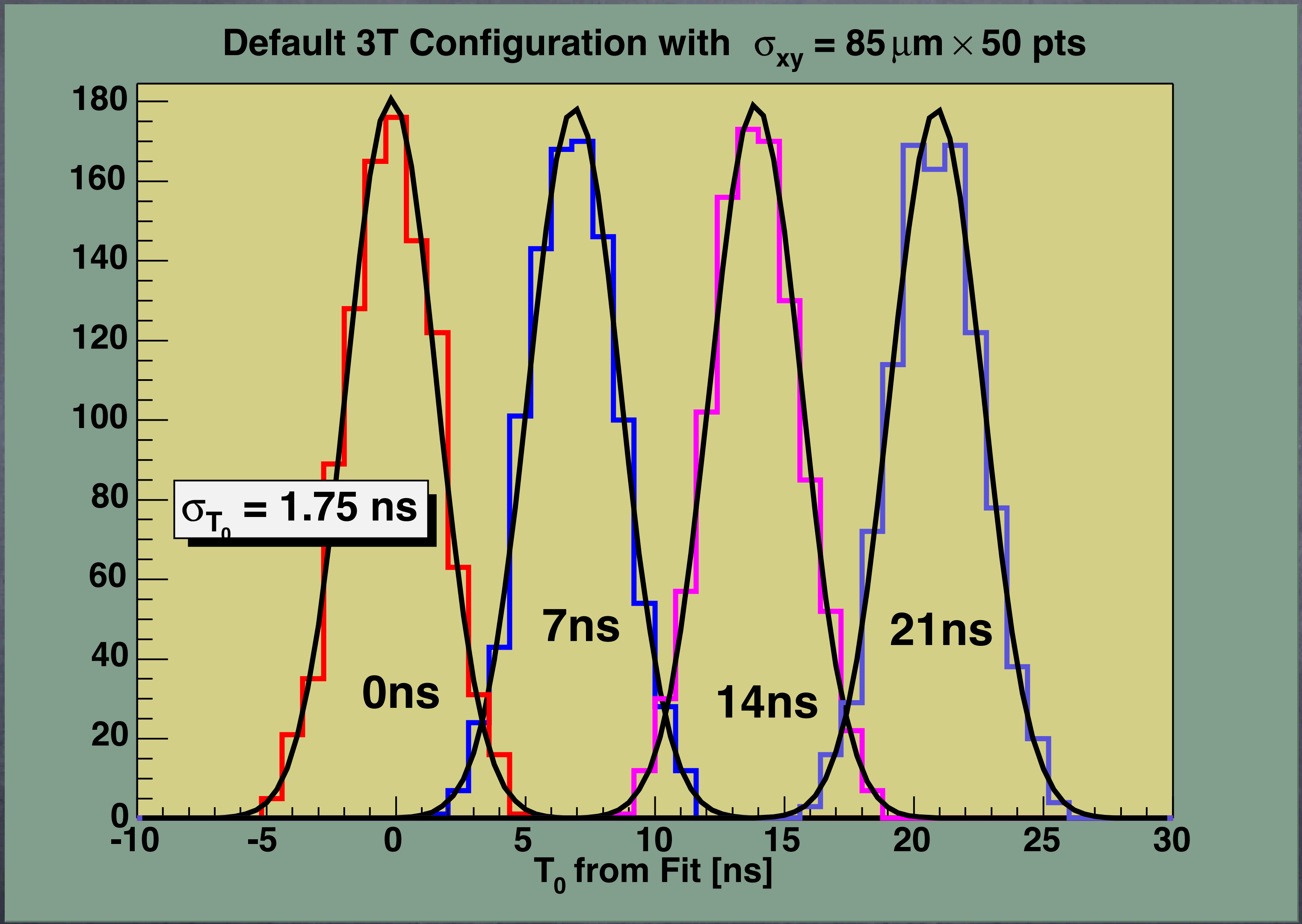


We can determine T0 with ~1.8ns accuracy as expected!

What happens if we add stereo layers?

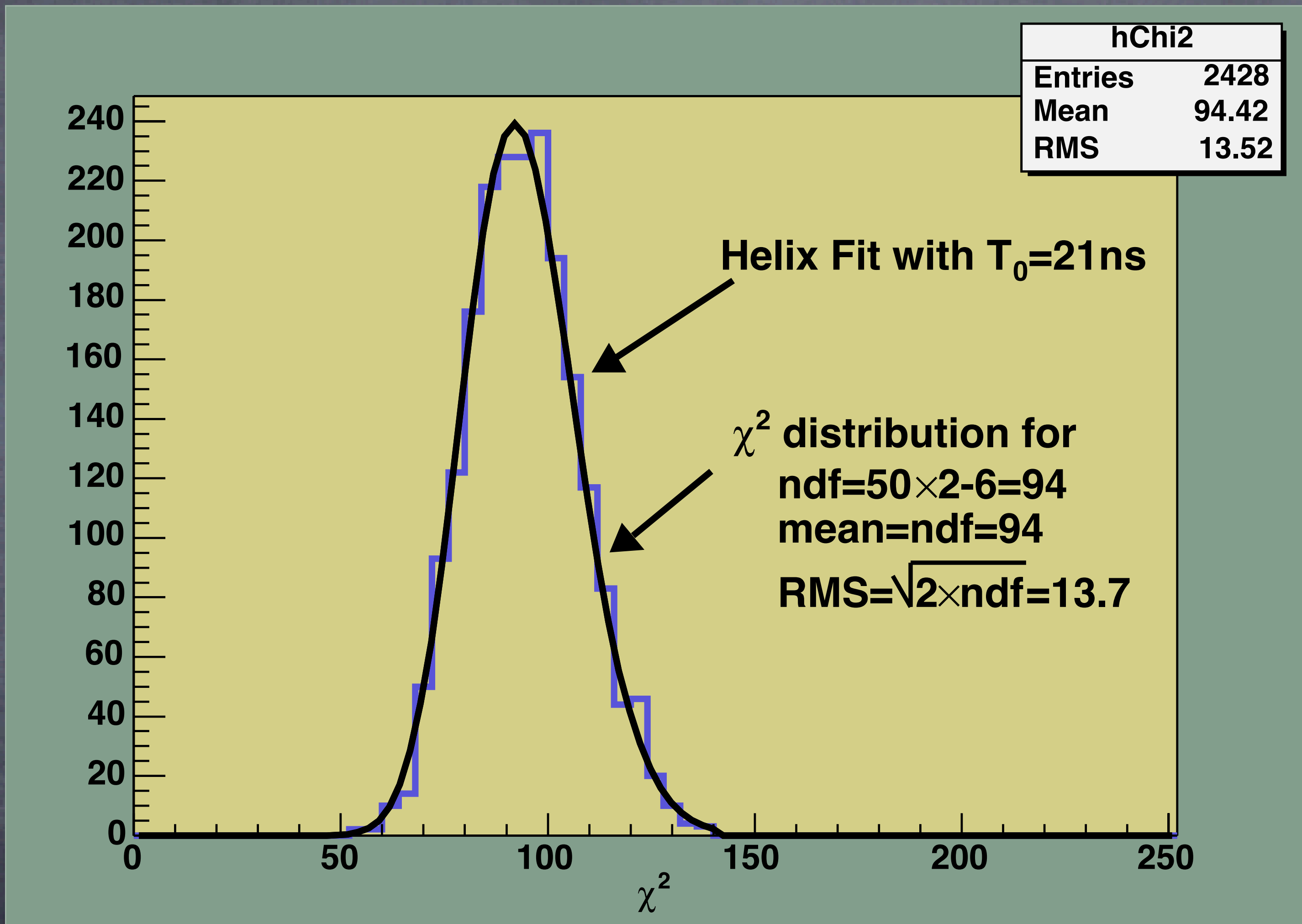
At certain Z positions, we lose L/R staggering of the neighboring layers!

Stereo layers allow additional freedom to eliminate track discontinuity by adjusting dip angle!

----> Degradation of time stamping capability?

- Chi2 Distribution (axial+stereo, 100GeV)

Chi2 Distribution (axial+stereo, 100GeV)



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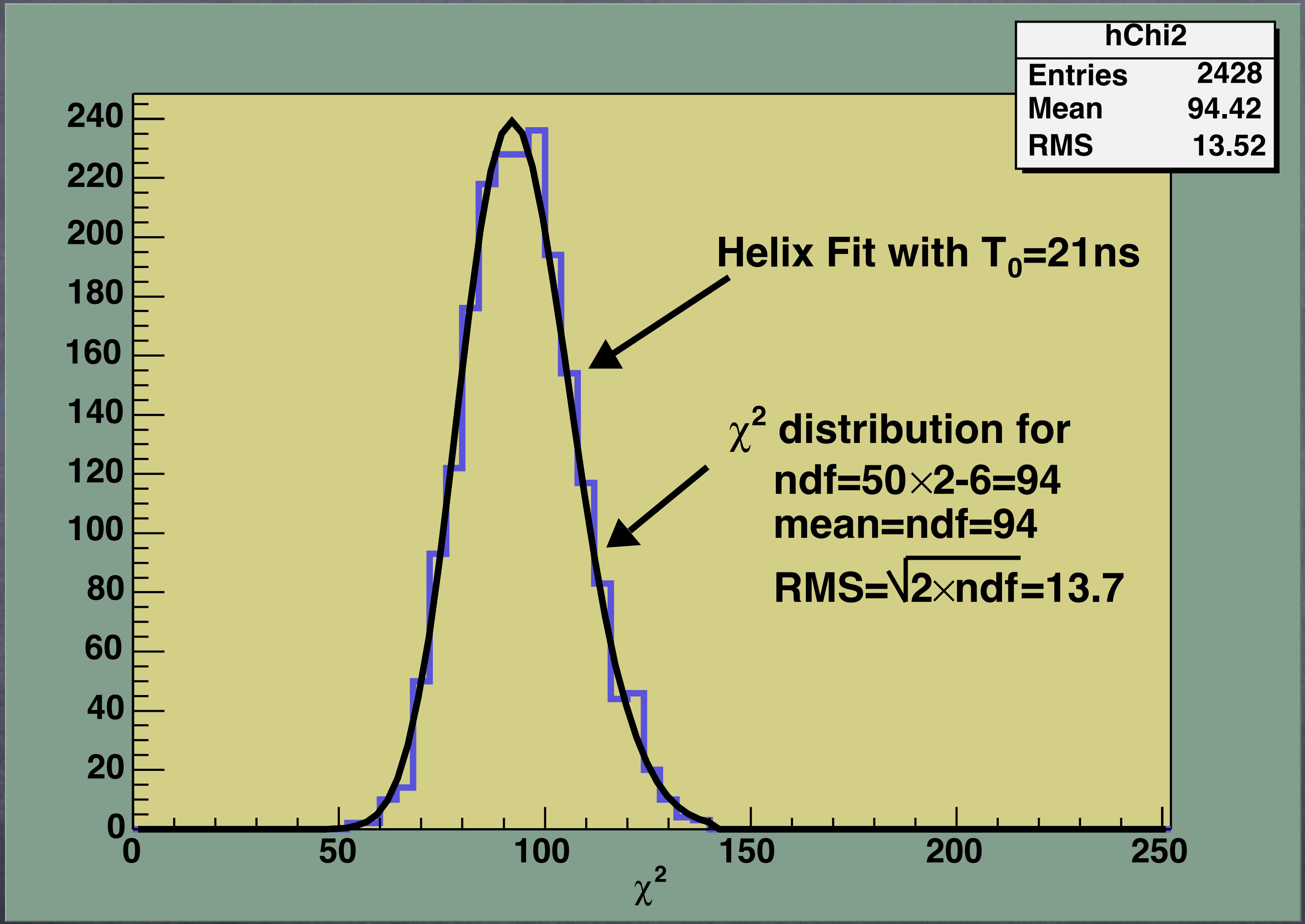

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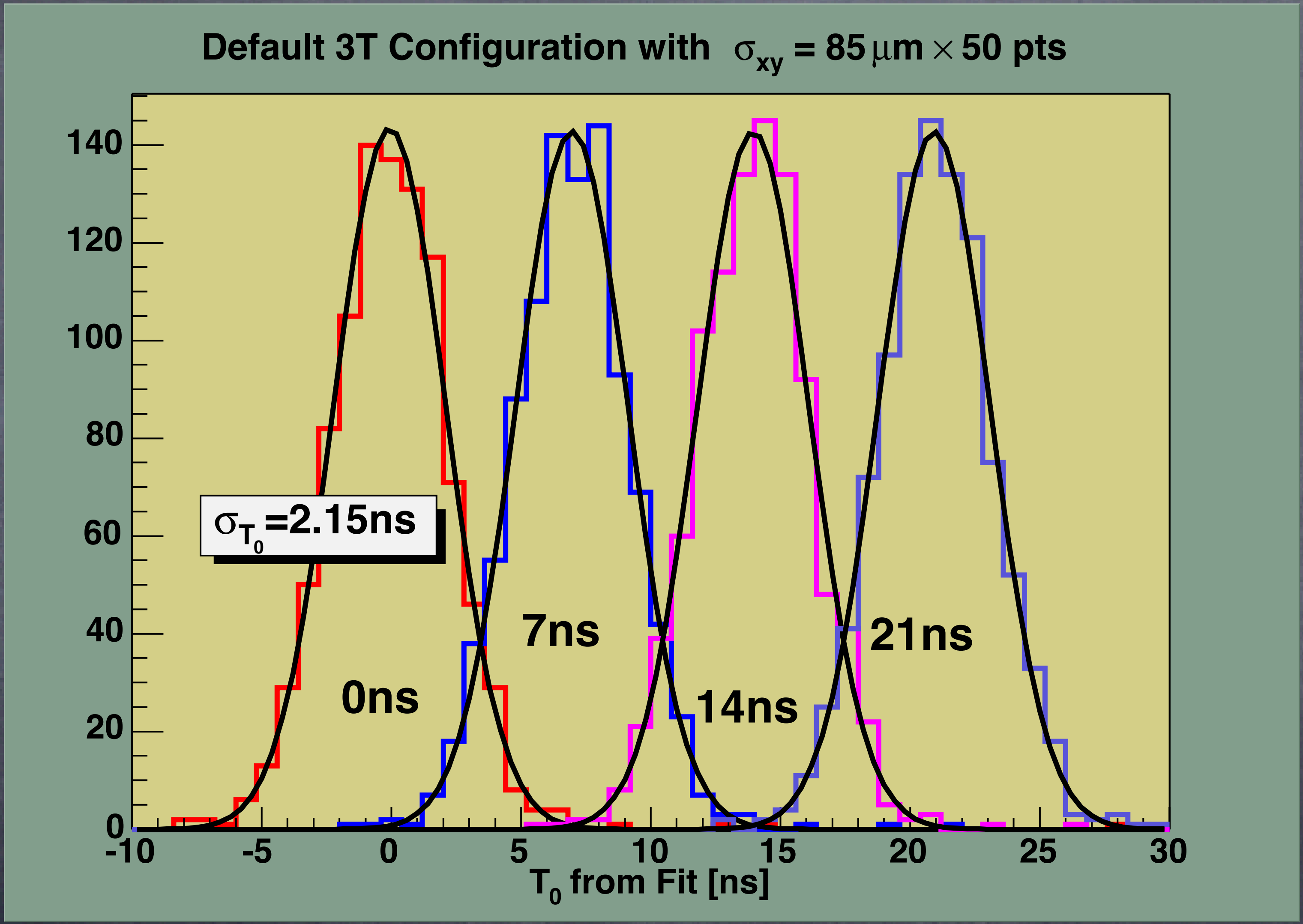

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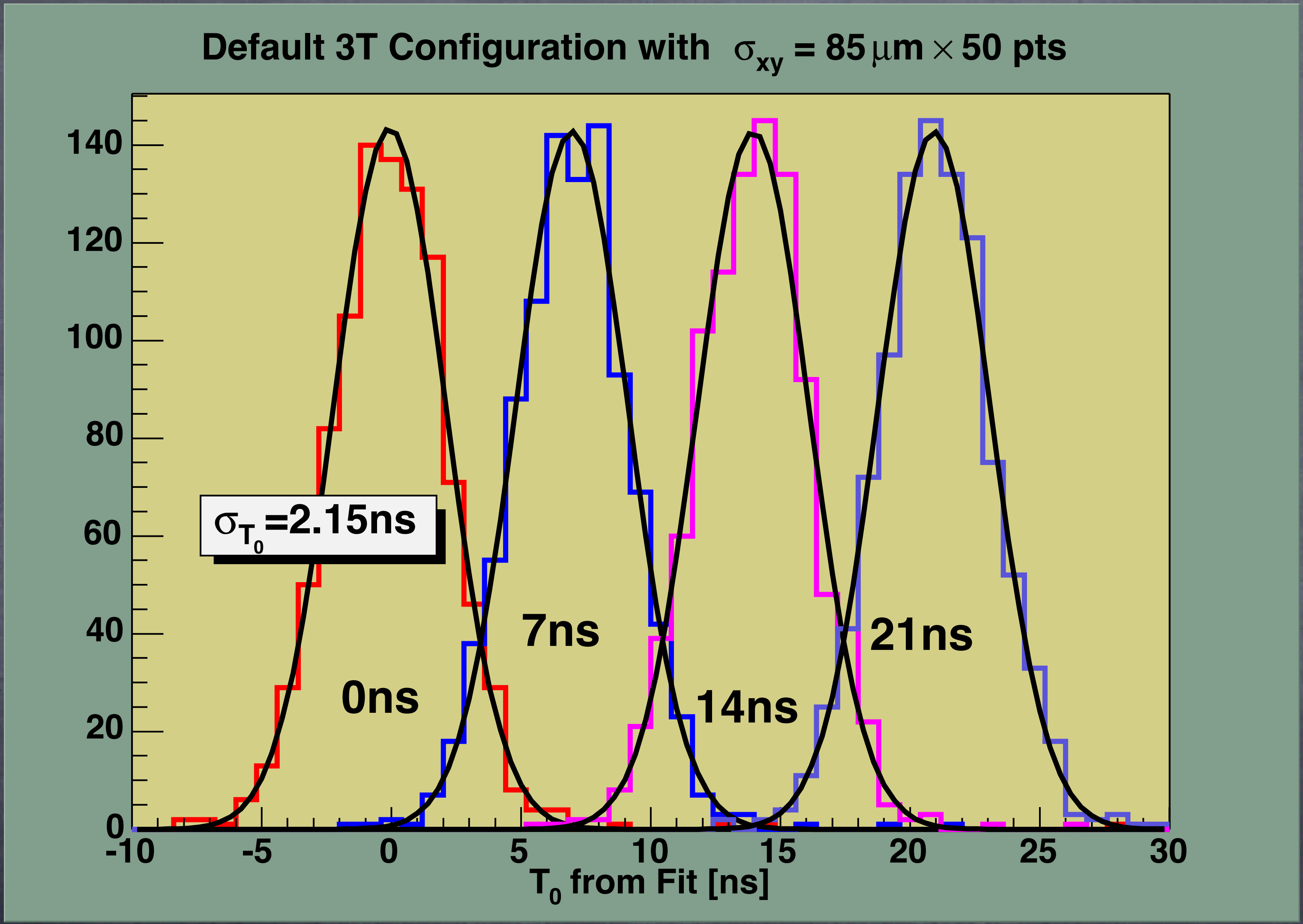


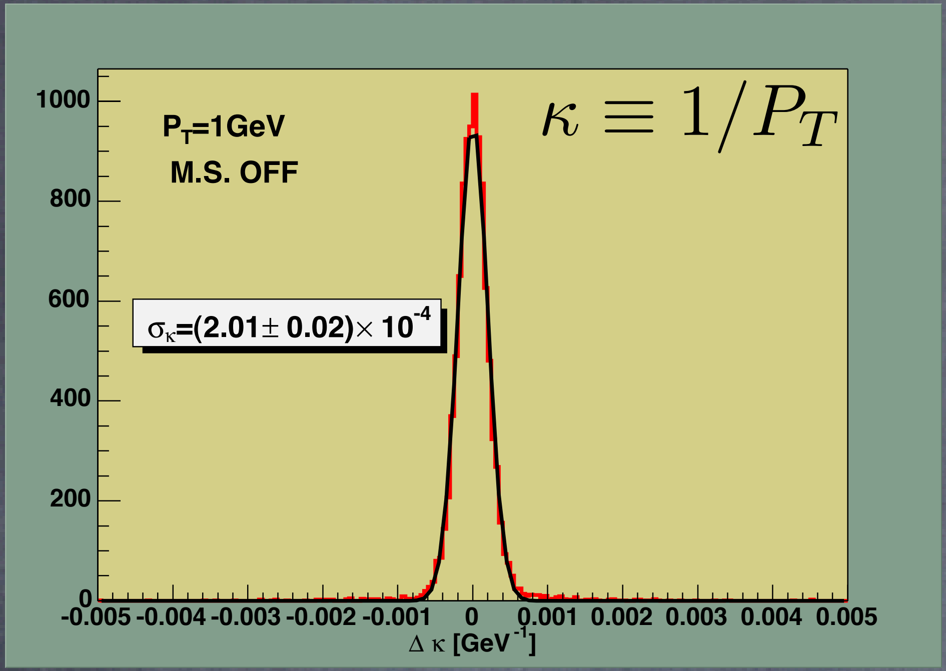
We can still determine T0 with ~2.2ns accuracy!

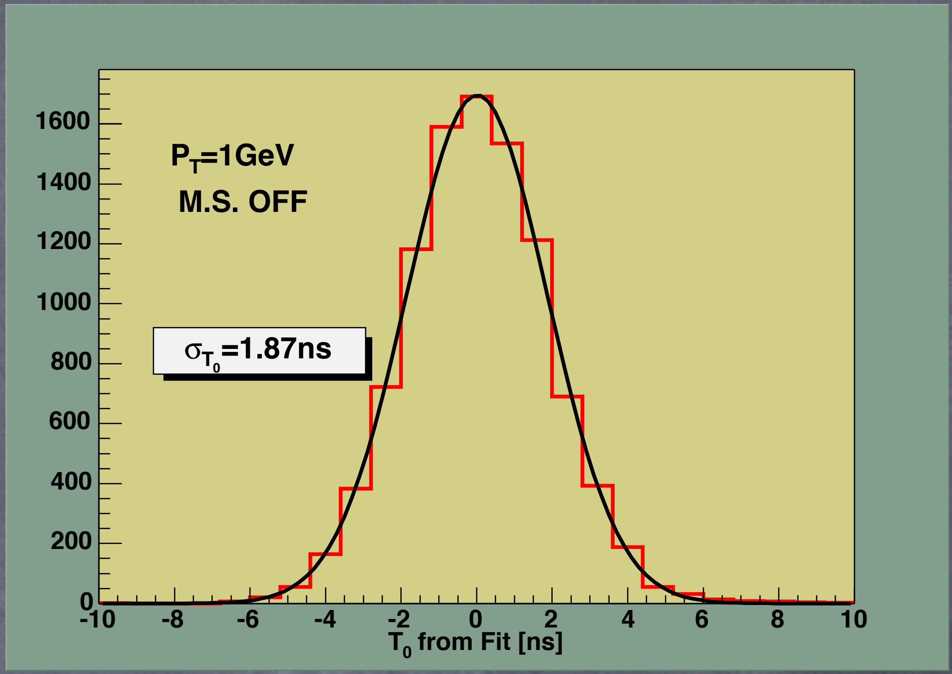
What about Low Pt Tracks?

- Multiple Scattering Effects (axial+stereo, 1GeV)

Multiple Scattering Effects (axial+stereo, 1GeV)

MS OFF





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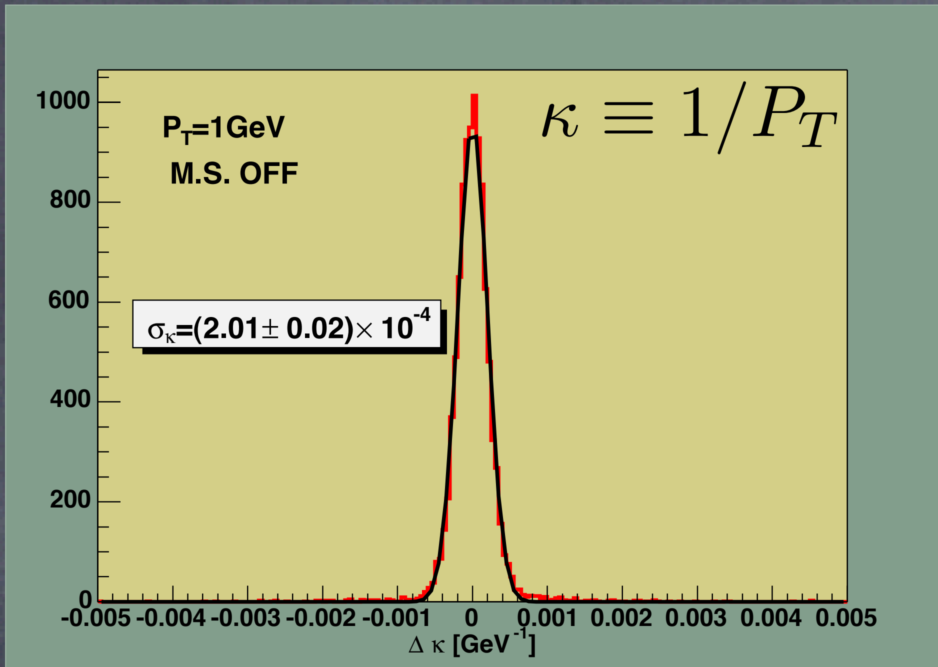

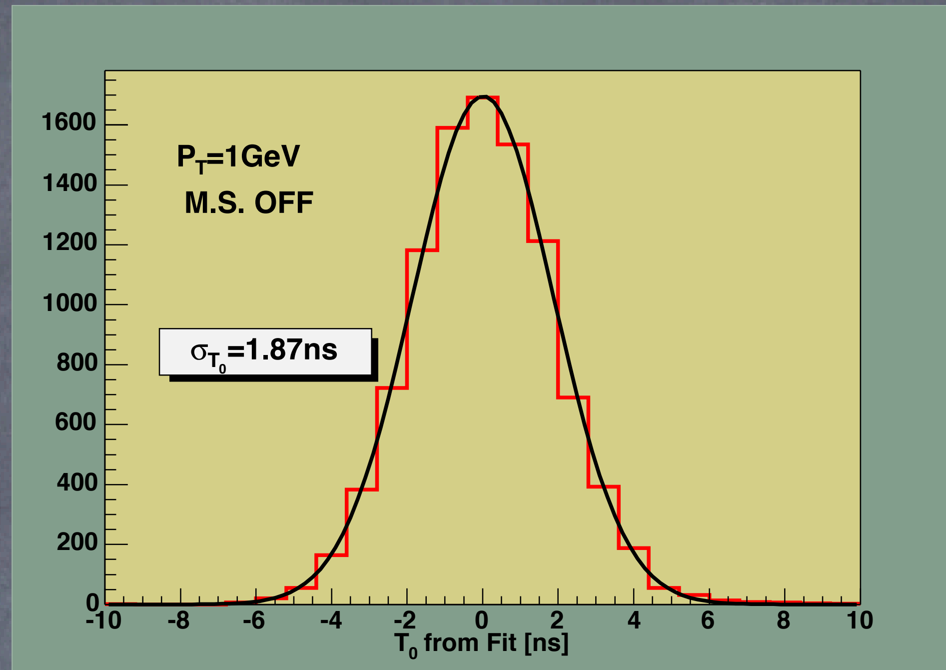

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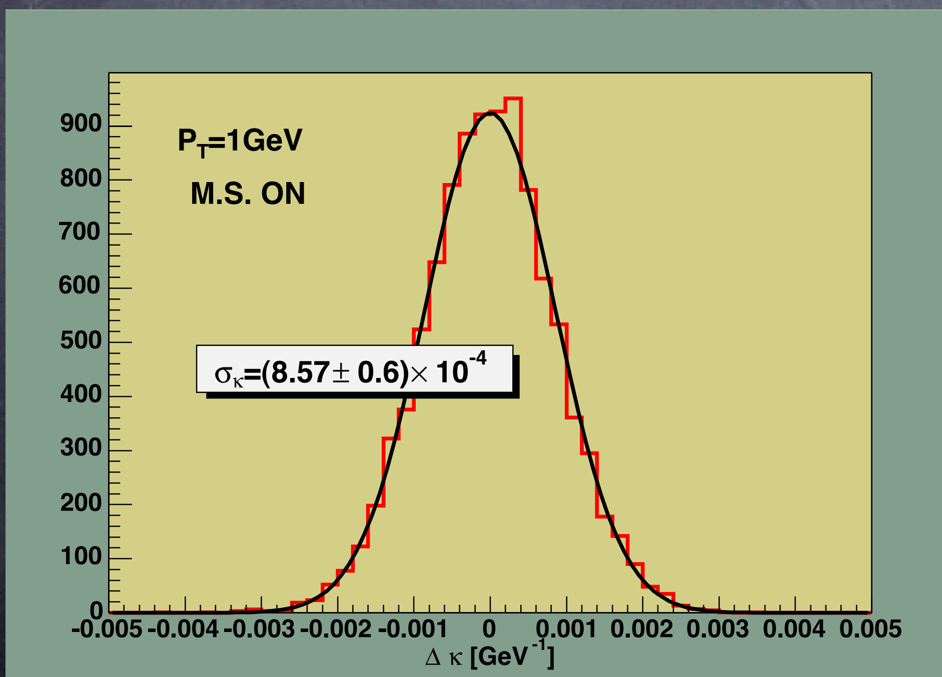

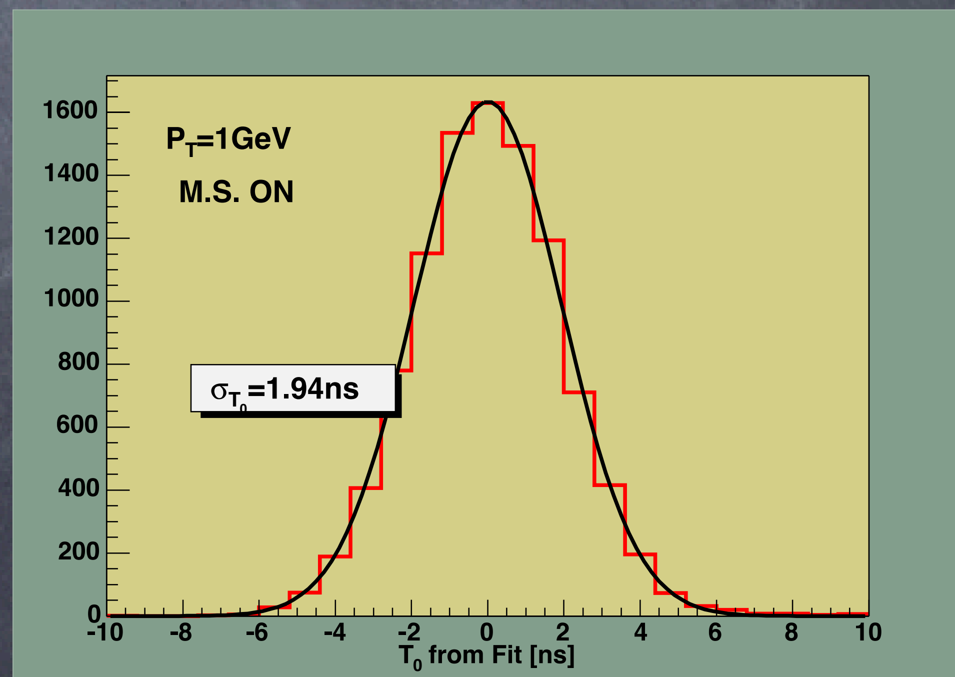

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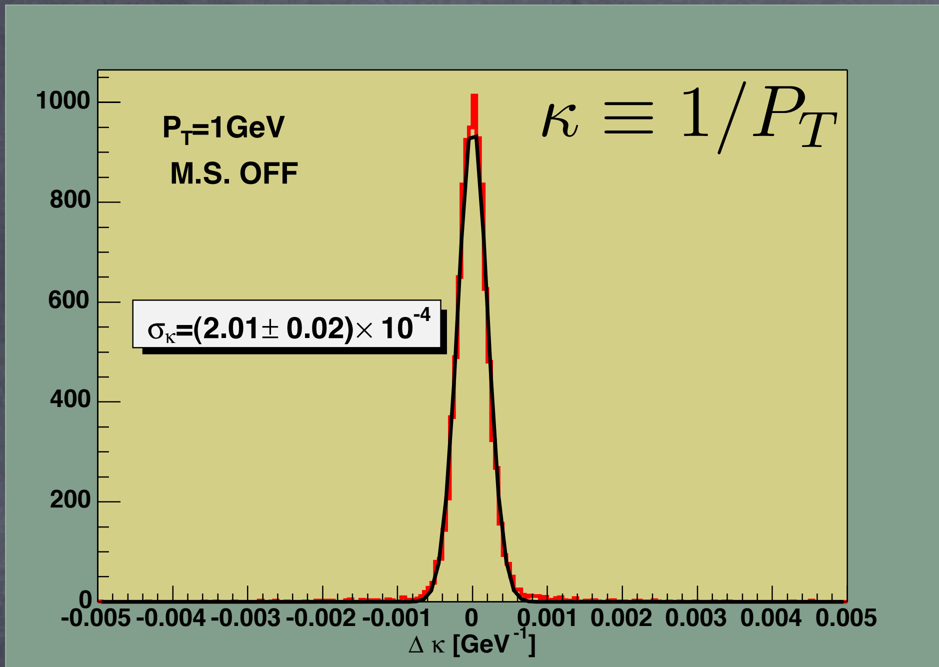
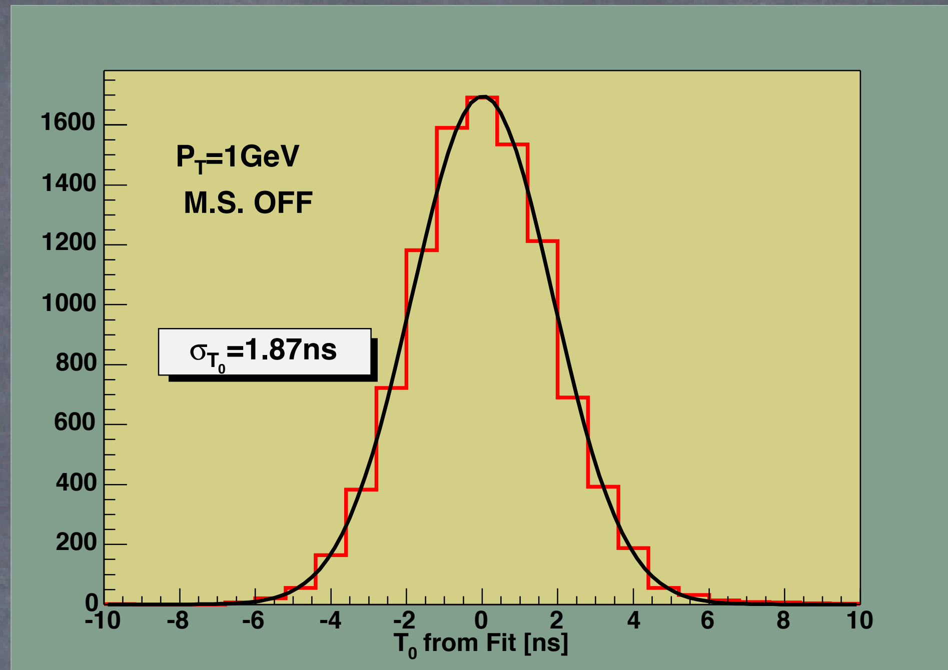
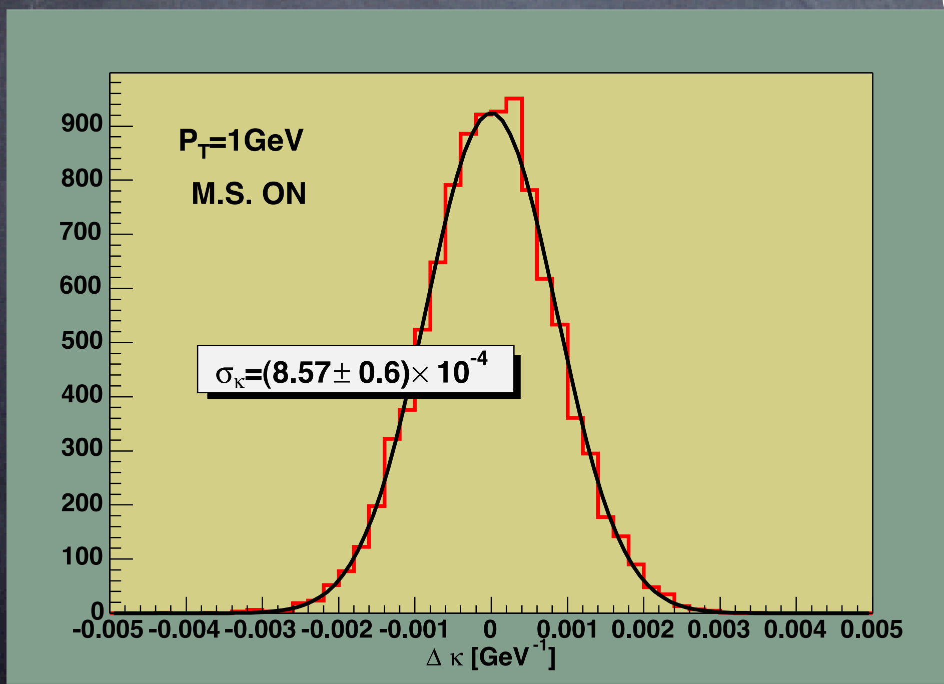
MS OFF

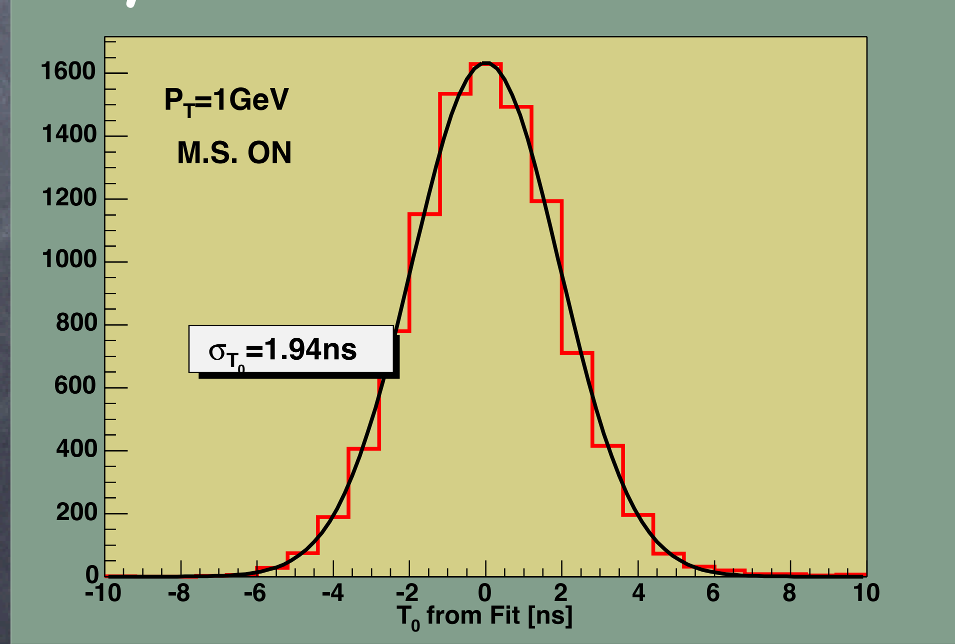




Only Small Effect on T0

MS ON





In the Case of TPC

Assuming a generic TPC with

$$R_{out} - R_{in} = 120 \text{ cm}$$
$$\sigma_{\rm xy} = 150 \ \mu\text{m}$$
$$\sigma_{\rm z} = 500 \ \mu\text{m}$$
$$B = 4\text{T}$$
$$n = 120$$
$$v_{\rm drift} = 5 \text{ cm}/\mu\text{s}$$

and a T0 device with

$$\sigma_{\rm z}^{T_0} = 10 \ \mu\text{m}$$

Helix Fit TPC hits Including the External Z Hit with T0 as an Additional Fit Parameter

- T0 from Helix Fit (d=5cm, 100GeV)

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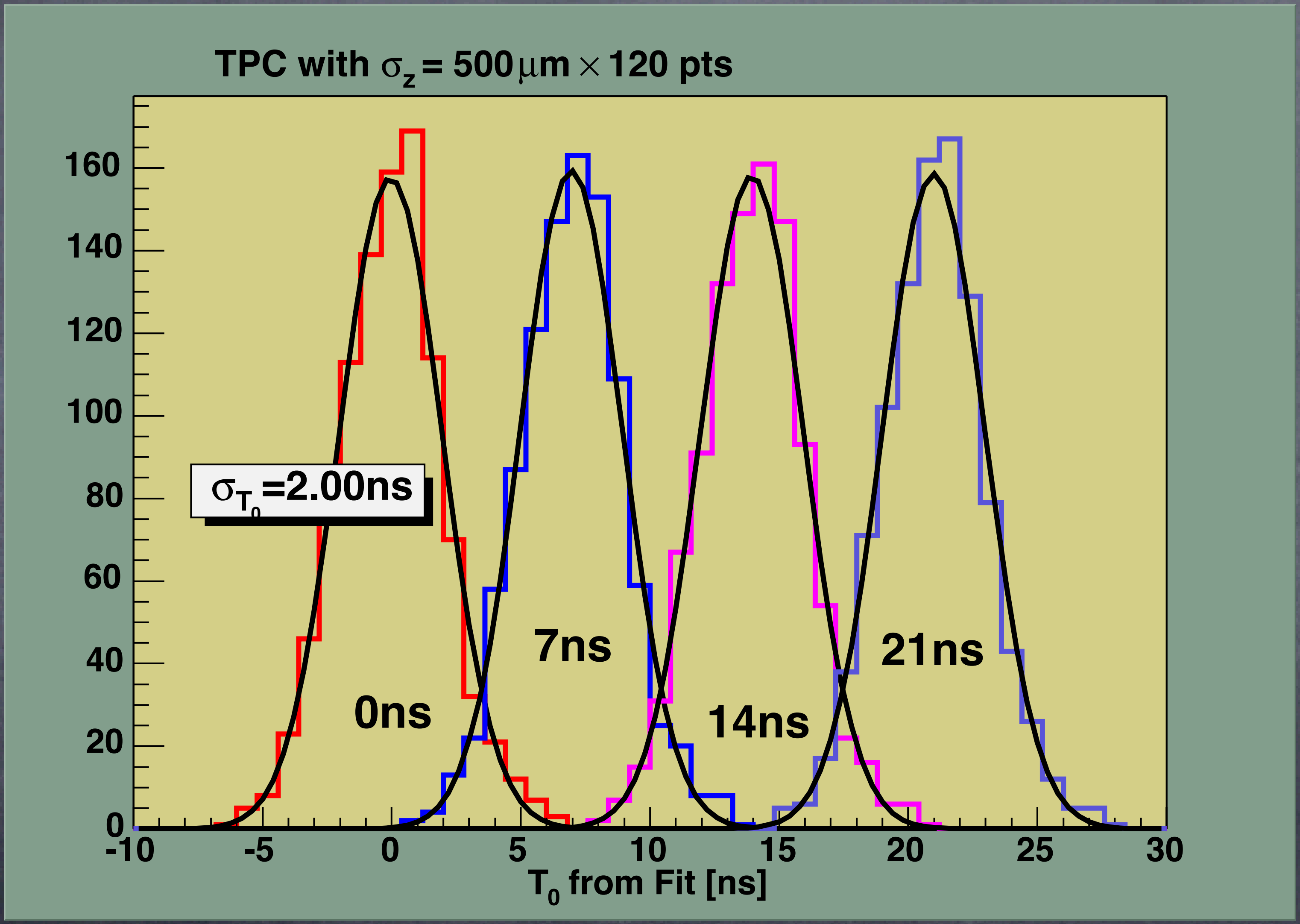
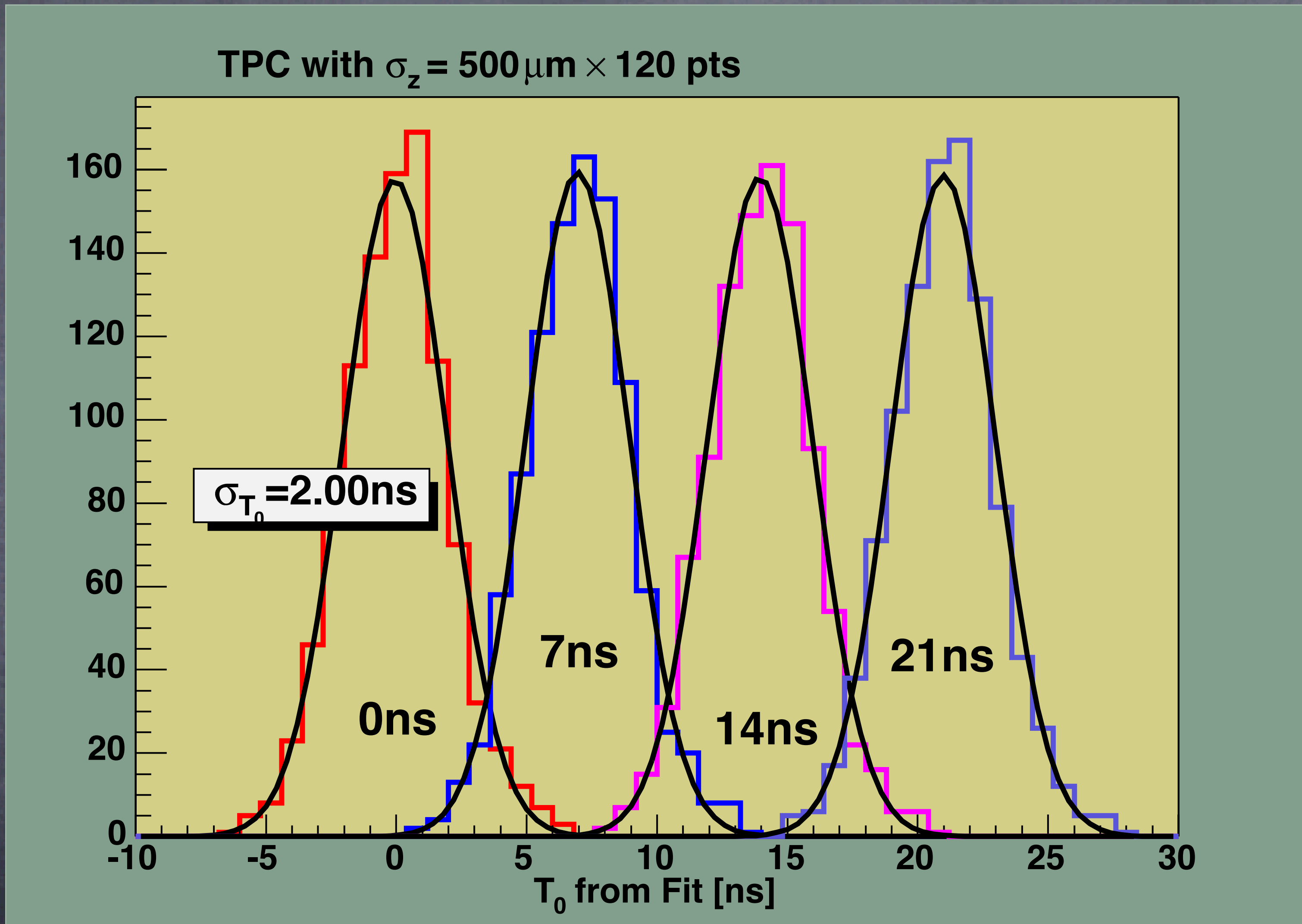


T0 from Helix Fit (d=5cm, 100GeV)



We can determine T0 with ~2.0ns accuracy as expected!

What about Low Pt Tracks?

- Multiple Scattering Effects (d=5cm,0.6%X0, 2GeV)

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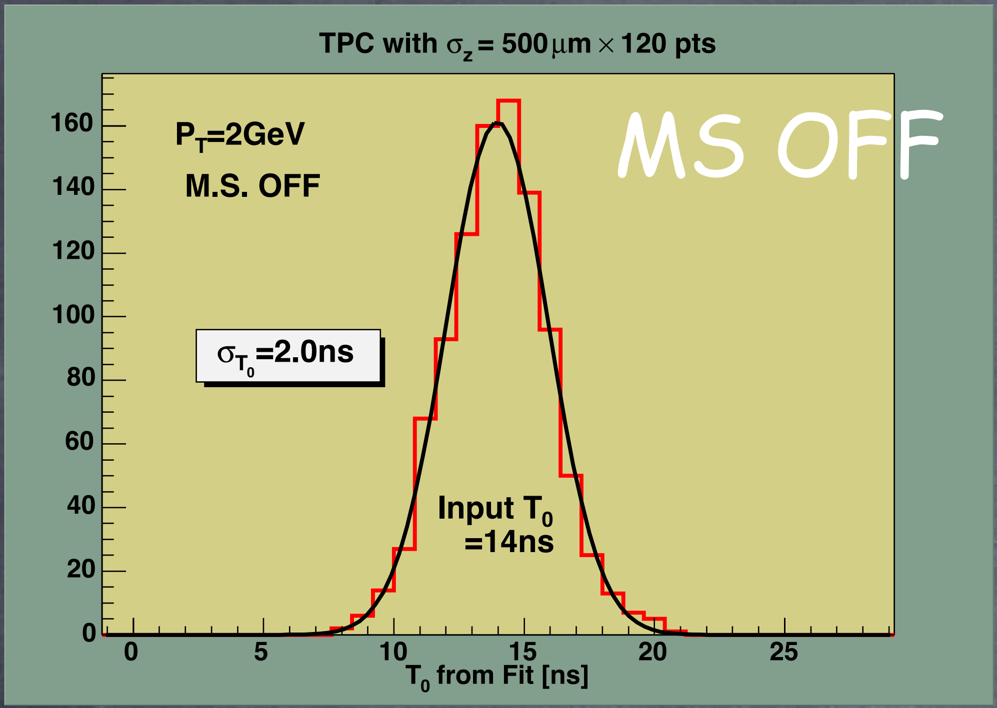
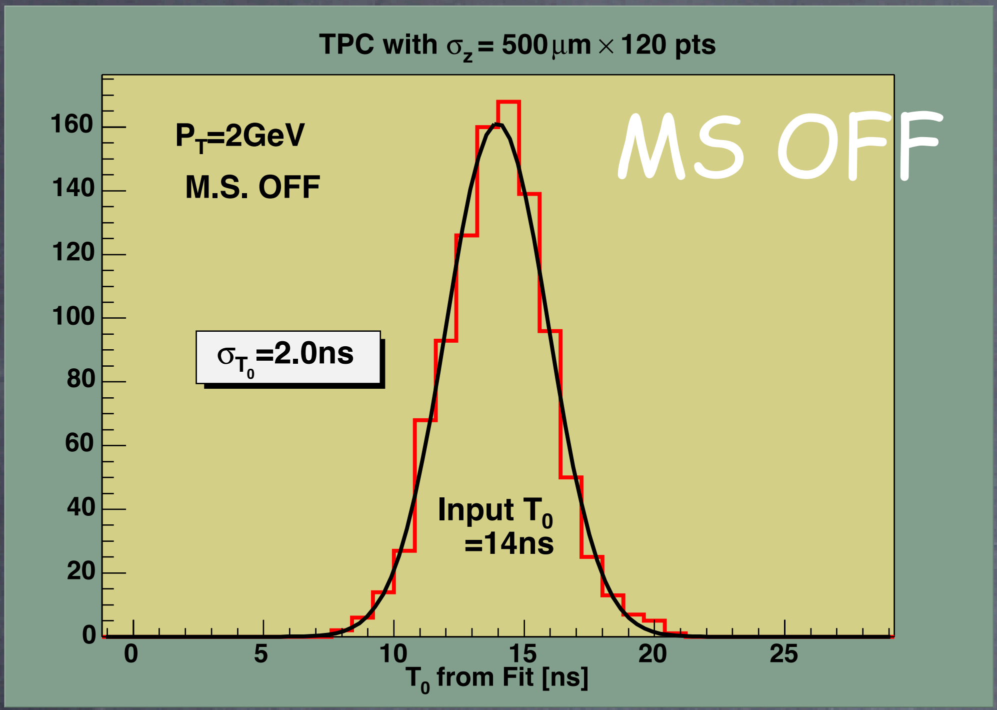
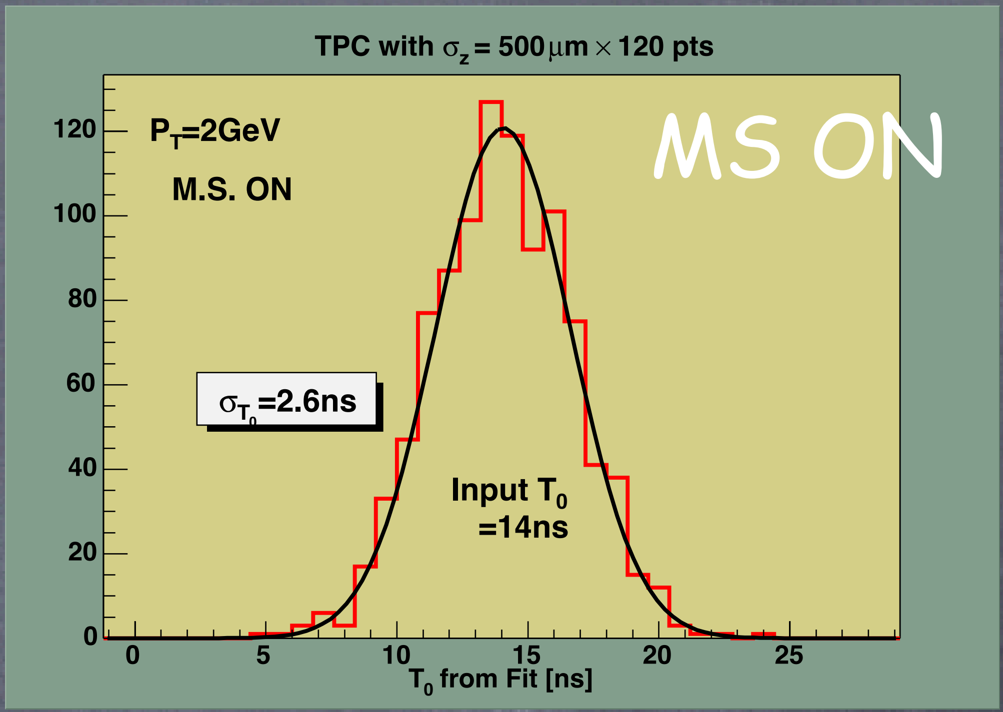


MS OFF

Multiple Scattering Effects (d=5cm,0.6%X0, 2GeV)





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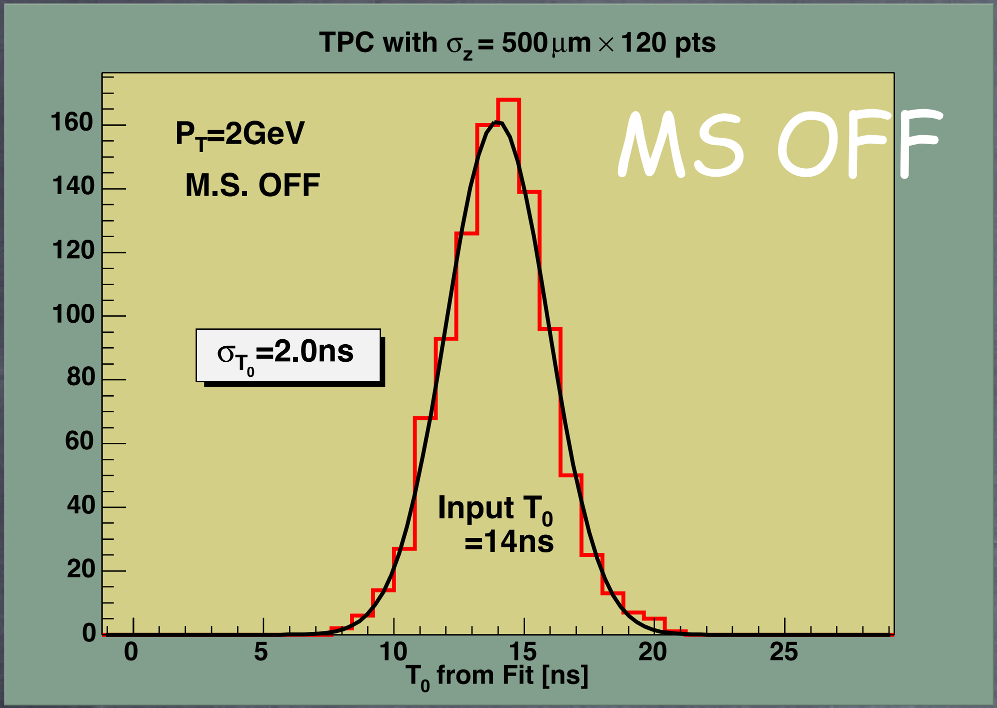

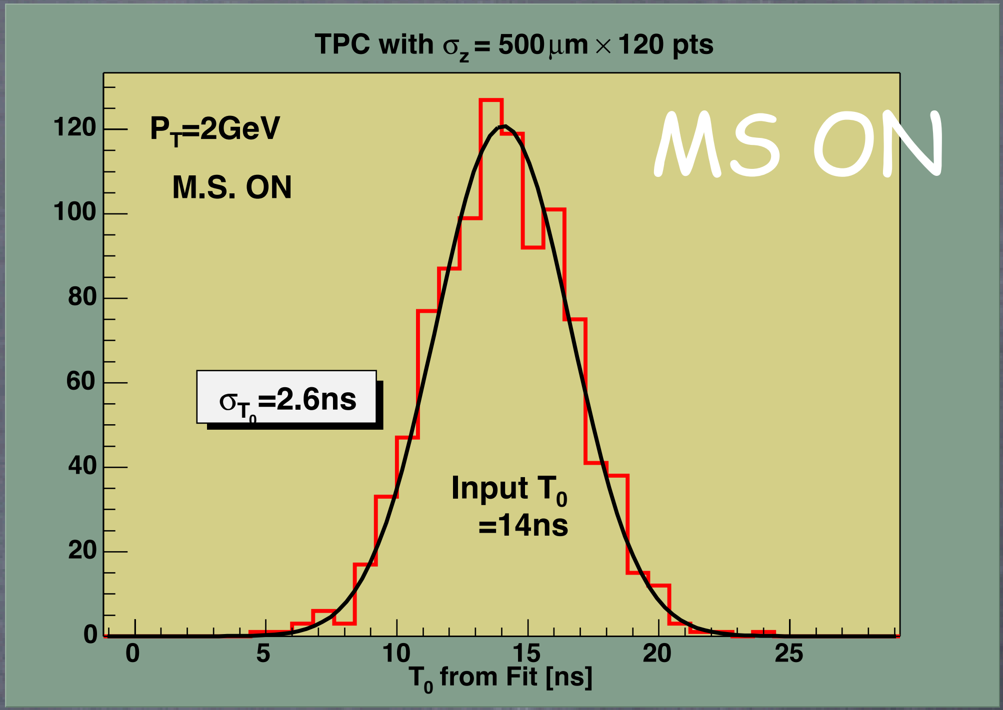

MS Effect more significant than for CDC

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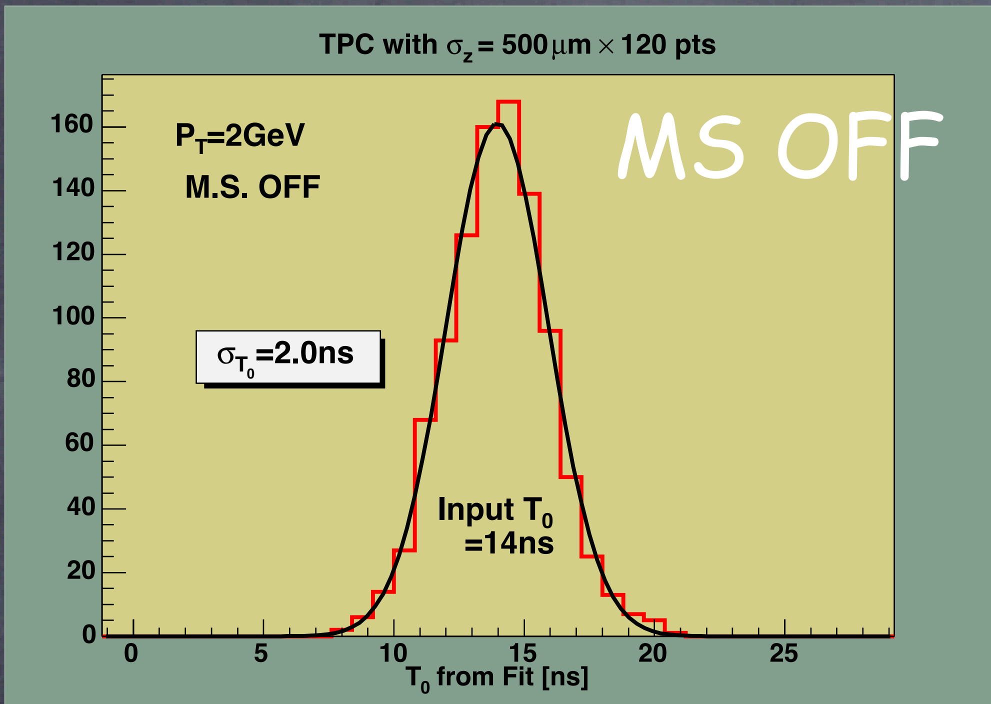

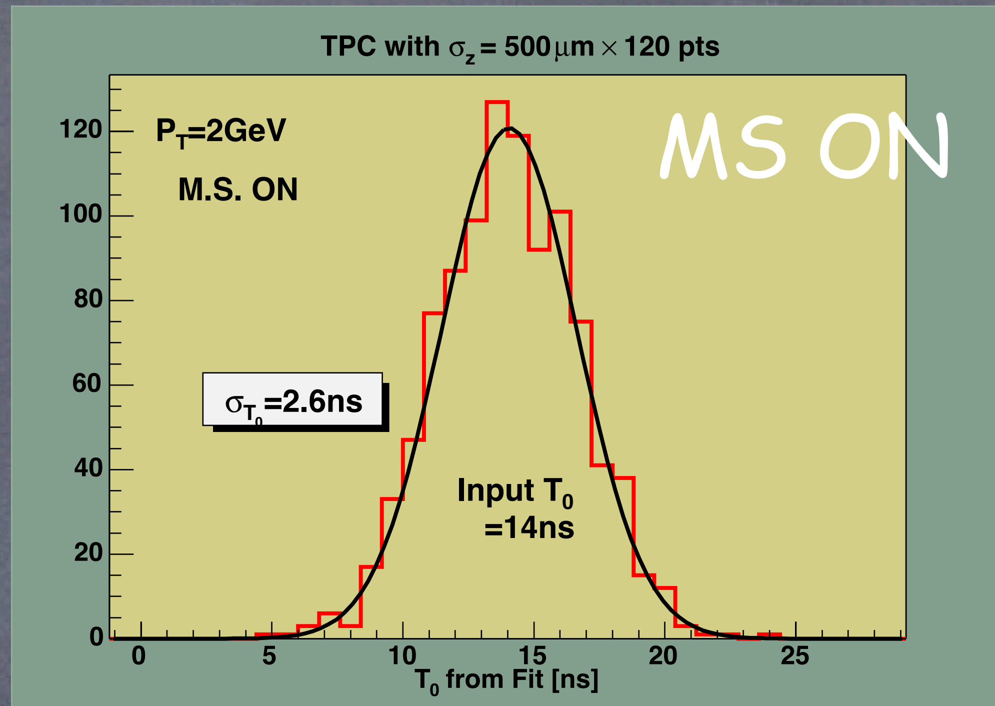

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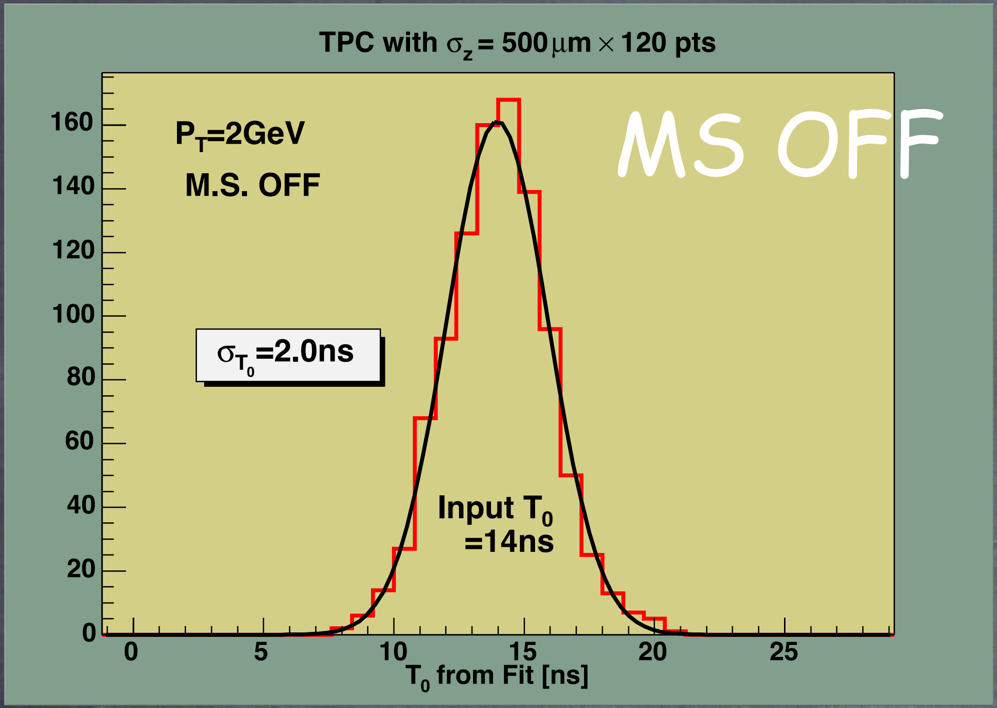

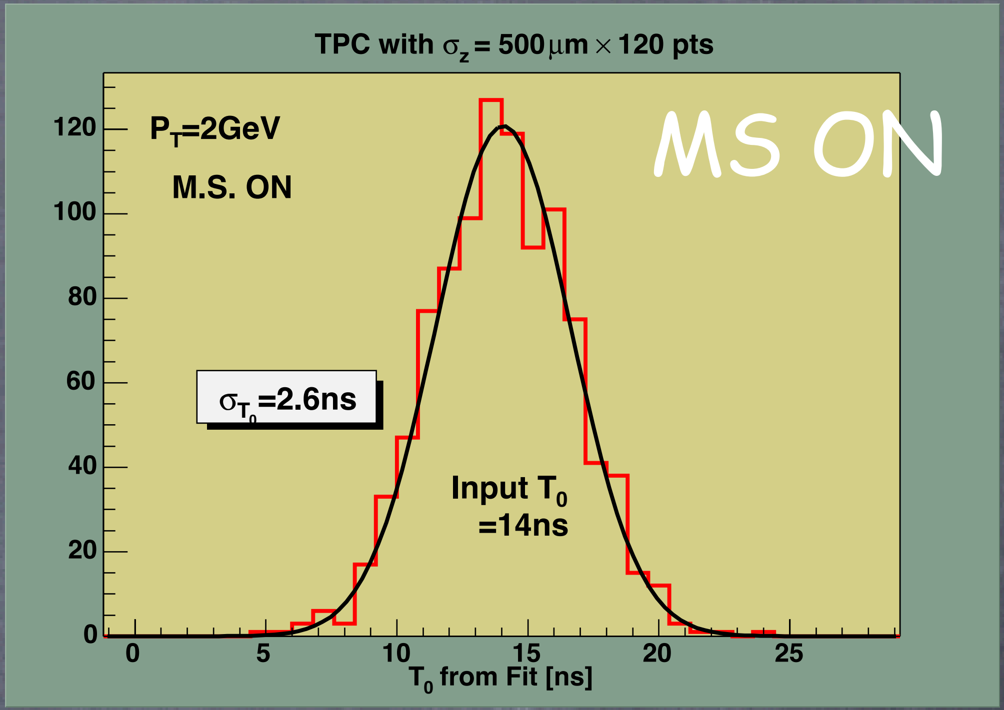

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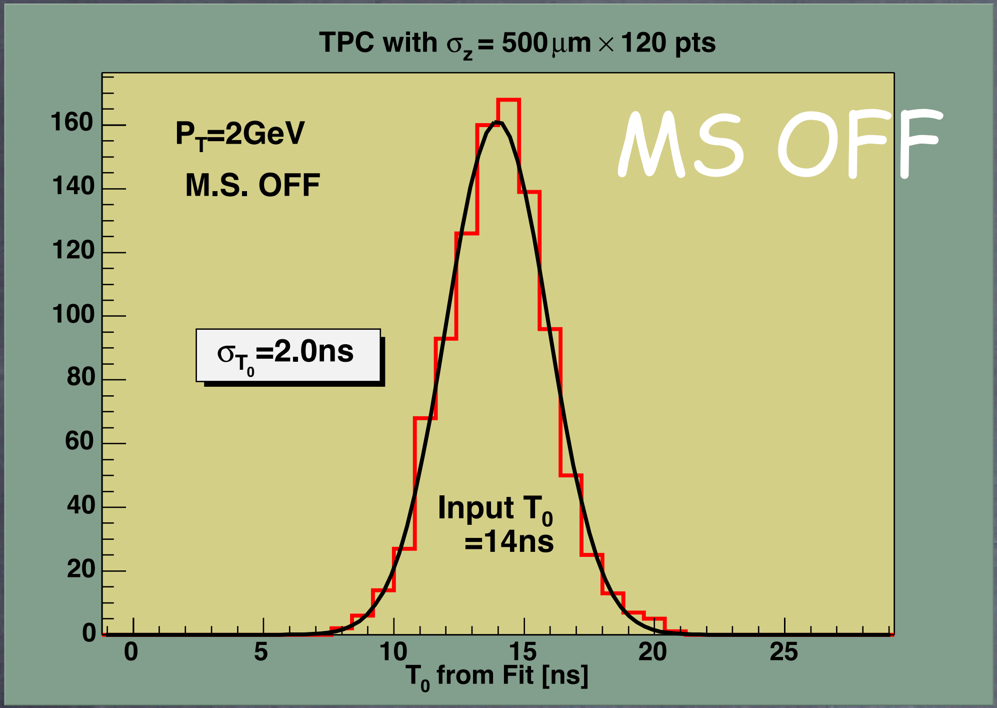

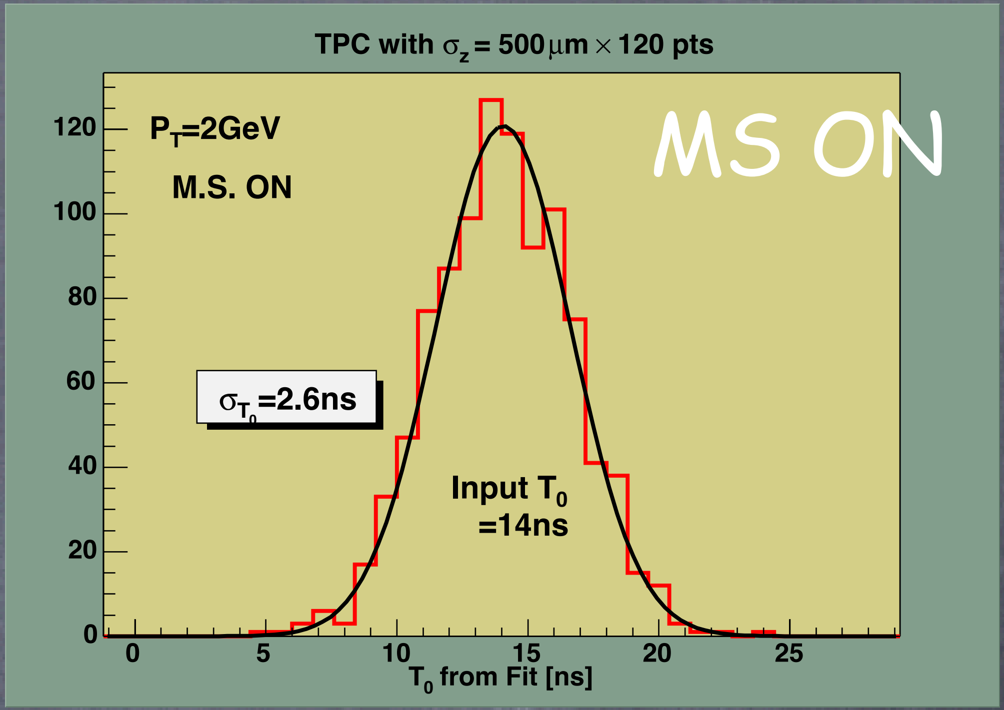

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0.6%X0 to 3.0%X0 --> 2% shift in T0 resolution

Summary & Conclusions

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- TPC can determine T0 together with a T0 device with a similar precision.
  - Multiple scattering effect is, however, more significant.

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  - Repeat everything for multi-jet events.